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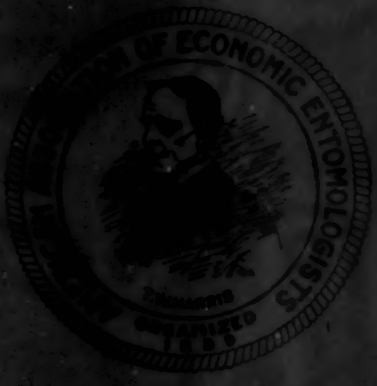

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Proceedings of the Forty-Second Annual Meeting of the American Association of Economic Entomologists

(Continued)

Wednesday Morning Session, January 1, 1930

The session convened at 9:50 a. m., President T. J. Headlee presiding.

PRESIDENT T. J. HEADLEE: The first paper is by Harry R. Bryson.

A STUDY OF FIELD PRACTICES AS RELATED TO WIREWORM INFESTATIONS (ELATERIDAE)[1]

By HARRY R. BRYSON, *Kansas Agricultural Experiment Station*[2]

ABSTRACT

Studies conducted at Manhattan, Kansas, from 1924 to 1929, inclusive, show that the percentage of corn plants injured by wireworms is influenced by the rate, date, and method of planting corn. Corn grown on land which had been cropped continuously to corn for 19 years showed less wireworm injury than that grown in various rotations. The studies indicate further that the sequence in which crops are grown in rotations, as well as the tillage methods employed in the preparation of the seed-bed, influence the amount of wireworm injury that may be expected.

Investigators in the field of subterranean insects are interested in the farm practices which influence the severity of infestations of insects attacking the roots of staple crops. The habits of wireworms are of particular interest in relation to field practices because of the difficulties involved in developing satisfactory methods for their control.

While conducting investigations pertaining to the life history and feeding habits of the true wireworms at this station, the writer had an opportunity to make observations and infestation counts, covering a

[1]Contribution No. 379, from the Department of Entomology.

[2]The writer wishes to express his appreciation to Prof. Geo. A. Dean, and to Prof. J. W. McColloch for their kindly suggestions in the preparation of this manuscript and to members of the Department of Agronomy at the college for their cooperation in making possible the field studies described herein. Acknowledgment is also made to Mr. Sam G. Kelly, student assistant, for his worthy assistance.

period of six years, from 1924 to 1929, inclusive, on corn grown under controlled conditions at the college farm on land subjected to various cropping practices. These studies were extended over a period of years because, first, many of the wireworms require from three to five years in which to complete their life histories, and second, because severe infestations do not ordinarily occur successively for a period of years at this station.

The following discussion is not presented as an exhaustive study of cropping practices and their relation to the wireworm injury problems, but rather as a progress report on preliminary studies that may prove valuable to workers interested in control methods for this group of subterranean insects.

METHODS. The studies recorded in this paper were begun in the spring of 1924 on plots and fields subjected to various cropping systems and different cultural methods. An effort was made to determine the effect which the date, method, and rate of planting corn would have upon the per cent of wireworm injury resulting under these conditions. Plots on which corn had been grown continuously for 19 years were compared with those on which had been practiced different systems of crop rotation. Notes, recording observations and infestation counts, were also taken on corn planted on plots handled according to various tillage practices in the preparation of the seed-bed.

Corn, observed on the date and method of planting, was planted at ten-day intervals, beginning with March 31 and ending May 20. One series each was listed, planted in an open furrow, and on the surface. This arrangement afforded excellent opportunity for observations to be made on corn planted according to these methods on the dates indicated.

The hills were spaced in the row from four to thirty-two inches apart at intervals of four inches in the rate of planting tests, each of which was replicated twice. These series were planted approximately on the same date each year, except in 1929, when a rate and date of planting plot was introduced into the series. The rate and date of planting will be discussed separately from the regular rate of planting.

The continuous corn area consisted of thirteen one-tenth acre plots treated with various fertilizers and planted to corn continuously for a period of 19 years. For the purpose of these studies, the counts on individual plots are not recorded separately since the series is treated as a single field. Data were also taken on a series of plots, planted the same date but subjected to different dates of plowing in the preparation of the seed-bed in order to determine, if possible, the effect of such practices upon the amount of wireworm injury.

The total number of plants and also the injured ones were counted in each plot or series of plots, each year except in 1924, when only the total number of hills and the injured hills were counted. All counts were made when the corn measured four or five inches in height and, consequently, were not taken on the same date each year. The stage of growth at which counts were taken varied but little one year after another. Only injured plants, which appeared above the surface, were counted. No data were taken on the number of kernels destroyed by the larvae, or the injured plants which never appeared through the soil. In 1929, the wireworms were dug out of the hills in a series of badly infested plots on which were practiced different tillage methods and retained for rearing purposes.

PRESENTATION AND DISCUSSION OF DATA. Nature of Injury. Wireworm injury to corn can be detected in most instances by the characteristic appearance of the tip or center leaf. This leaf is usually the first to show wilting after which it dries and turns brown, while the remainder of the leaves remain green. In cases of severe injury, the remaining leaves undergo a similar change. This characteristic injury is most noticeable when the plants are four or five inches in height and is caused by the larvae attacking the plants above the first node from which the permanent roots are produced. A small, round hole is eaten into the center of the stalk, thus cutting off the water and food supply from the central parts above the point of injury. The plant wilts down only when the entire center of the stalk is destroyed. Observations show that very few plants, if any, actually recover from even the slightest injury. The plants showing injury were dug up and examined in order to be certain that they were injured by wireworms. This process was repeated when a new plot was encountered and at definite intervals during the count. In practically every instance, the characteristic injury or the larva was found; hence, every care was exercised to discriminate against injuries effected by agencies other than wireworms. Observations show that one wireworm is sufficient to injure an entire hill of corn, since a single larva does not always feed upon one plant until it is destroyed but may move to other stalks in the hill and attack them.

Further observations also show that a single larva may move down the row in which the corn is drilled and kill four or more plants spaced 14 inches apart. This is evidenced by the first plant being dead, the second partly wilted, the third with the central leaf wilted, while the central leaf on the fourth is beginning to wilt. If the last plant is examined, the wireworm invariably can be found. In some instances

where seed corn lies in cold, wet soil from ten to fourteen days before germinating, wireworms attack the seed; therefore, injury to the seed is less likely to occur when its germination is not retarded.

RATE OF PLANTING.—The data, herein presented to show the effect of planting corn various distances apart, indicate, in general, that the per cent of injury increases as the distances between the plants are increased. Plantings were made approximately the same date each year and the counts were taken at the same stage of growth.

An examination of the data presented in Table 1 shows that the hills were counted in 1924 while the plants were recorded for the remaining years. In computing averages, the number of hills are considered as plants, because in this particular instance there was only one stalk to the hill. In any event, the relative amount of injury occurring at the various distances bears the same relation to each other.

In 1925, there were two plants to the hill; in 1927 to 1929, each hill had but one. However, the data taken in 1928 and 1929 were based upon two rows out of the four series. The area devoted to the rate of planting plots was not located in the same place on the farm each year but the sequence of crops on the land, previous to being planted, was the same. Approximately three years elapse before the plot is again planted on the same soil. An effort is made to keep the plots on the same soil type so that the data obtained from year to year are comparable. Data taken in 1926 were omitted from Table 1 because of the inaccuracy involved in distinguishing a few wireworm-injured plants from severe injury caused by cutworms.

If the number of plants and the number of injured ones be determined for each distance each year and the percentage of injured plants calculated, it is possible to show the effect of different spacings upon the per cent of injury. An examination of Table 1 shows that 1924 and 1925 were years in which there occurred the heaviest wireworm injury.

The "average column" at the extreme right in the table was computed by adding the total number of plants for all years and the number of injured plants for the same years and from these calculating the percentage of injury for each spacing for five years.

A further examination of the average column shows that the lowest injury, one and forty-three-hundredths per cent, for the five-year period, occurred where corn was planted four inches apart in the row. The space between the rows was the regulation distance of 42 inches used in planting corn in the general fields at Manhattan. Plants spaced 8, 12 and 16 inches apart showed injury resulting from the attacks of wireworms to the amount of 2.01, 1.88 and 1.98 per cent injury, respectively.

TABLE 1. PERCENTAGE OF WIREWORM INJURY TO CORN PLANTED AT DIFFERENT RATES FOR A FIVE-YEAR PERIOD

Distance Apart	1924			1925			1927			1928			1929			Per cent of Injury for the 5-Year Period
	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	
4 inches	2182	108	4.77	4312	17	.39	2353	1	.04	1091	1	.09	637	24	3.77	1.43
8 inches	1174	84	7.15	2422	17	.70	1152	5	.43	515	3	.58	1081	19	1.76	2.01
12 inches	797	54	6.77	1635	4	.24	775	5	.65	327	3	.91	722	14	1.94	1.88
16 inches	608	55	9.05	1223	7	.57	589	0	.00	328	1	.34	1139	14	1.23	1.98
20 inches	483	47	9.73	1037	3	.29	541	2	.37	222	1	.45	427	22	5.13	2.77
24 inches	395	70	17.72	844	7	.83	475	2	.42	175	1	.56	295	26	8.81	4.85
28 inches	343	62	18.08	700	10	1.43	382	4	1.05	161	0	.00	94	15	15.95	5.42
32 inches	280	67	23.93	640	7	1.09	406	1	.24	128	0	.00	91	14	15.38	6.16

Those planted 20 inches apart showed a definite increase over the amount of injury recorded for the shorter distances.

The plants spaced 24 inches apart indicated a marked injury of 4.85 per cent as compared with 2.77 per cent in the 20-inch planting. The data show a gradual increase in the percentage of wireworm injury beginning at the 20-inch spacing and ending with the 32-inch planting. This increase is attributed to the greater population of wireworms to the plant in the sparsely planted rows. Observations also indicate that injury is greater on drilled corn than on that which is checked. The total population of wireworms to the plot would be approximately the same for all plots. From the data submitted, one could assume that 20-inches apart would be the longest distance at which single plants should be spaced in order to avoid severe wireworm injury to the stand.

It is interesting to note that approximately five years intervened between the years on which severe wireworm infestations occurred. In some of the rearing work conducted at this station, the writer has found that the life histories of some of the collected larvae belonging to the genus Melanotus, which attack the roots of corn, extend over a period of four or five years. Further investigations will be necessary to determine whether or not there is any significance in this apparent relationship between the occurrence of wireworm infestations and the length of time required for the insects to complete their life histories. The temperature and moisture conditions in the spring of 1928 and 1929 were similar at the time of planting.

Rate and Date of Planting.—Two series of plots were introduced into the regular rate of planting tests in the spring of 1929. One planting was made on May 2, while the other was planted May 18. The plantings on each date consisted of a series of five plots each with spacings of the plants in the rows ranging from eight inches in the first plot to 24 inches in the fifth one. The two series were not replicated. The results of this test are shown in Table 2.

Table 2. Percentage of Injury to Pride of Saline Corn Planted at Different Rates on May 2 and May 18

Distance Apart	Planted May 2, 1929			Planted May 18, 1929		
	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured
8 inches	475	3	.63	575	0	0
12 inches	315	3	.95	253	0	0
16 inches	218	4	1.83	255	0	0
20 inches	193	6	3.11	195	1	.52
24 inches	144	7	4.86	159	2	1.26

An examination of the data presented in Table 2 shows that the time of planting influenced the amount of wireworm injury present.

Although 16 days intervened between the two plantings, there was very little difference in the height of the plants on May 27th, when the counts were made.

The percentage of injury for plantings made on May 2 increased from .63 per cent for corn spaced eight inches apart to four and eighty-six-hundredths per cent at 24 inches, with a marked increase in injury beginning at the 20-inch spacing. A similar increase for corn planted May 18 as a result of spacing is shown in column six. Since the plots were planted in close proximity to each other, with other environmental and edaphic factors similar, the variation in injury to either of the plots resulted after the date on which the counts were made.

TIME AND METHOD OF PLANTING.—A study of the work done over the five-year period to determine the effect of the time and method of planting corn upon the amount of wireworm injury shows a definite relationship existing between these factors and the percentage of injury. Table 3 gives a complete record of the counts made for five years of investigational work. Records were kept on the plots planted by the different methods at ten-day intervals, beginning March 31 each year and ending May 20. The percentage of injury is calculated for each date of planting for each year. The percentage of injury for each date of planting over the five-year period is recorded in the last column in Table 3.

A careful examination of Table 3 indicates that, for the five-year period, wireworm injury was more severe on corn planted April 10 and least severe on that planted May 20, irrespective of the method of planting used. Corn planted March 31 also suffered considerable injury. These facts show more vividly that slow germination and retarded growth are conducive to wireworm injury. The data in Table 2 also show that corn planted on May 18 revealed less injury than that planted on May 2. Observations also indicated that germinating kernels were injured when the corn was planted at the time wireworm attacks are most likely to occur, thus reducing the number of stalks in the row.

A comparison of the percentage of wireworm injury to which listed, open furrow, and surface-planted corn were subjected, shows that listed corn suffered least from the attacks of wireworms. The fact that the soil is thrown up in the form of a ridge reduces the possibility of attack because the seed is placed below the level frequented by the larvae at this time of year. Miles and Petheridge (1927) found in England that wireworms, *Agriotes obscurus*, are seasonal in their movements in the soil, coming upward in September, October, March, April and May, and going downward through autumn, winter and spring. From pre-

TABLE 3. PERCENTAGE OF INJURY TO CORN IN THE DATE AND METHOD OF PLANTING TESTS

Date	Total Plants	Injured Plants	Per cent Injury	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Per cent of Plants for Injured Five-year Period
								Listed								
March 31	172	6	3.49	180	0	0	174	2	1.15	76	0	0	120	0	0	1.11
April 10	170	16	9.41	177	0	0	167	0	0	154	3	1.94	96	0	0	2.49
April 20	176	13	7.38	186	1	.53	170	0	0	167	0	0	94	3	3.19	2.15
April 30	177	5	2.82	176	0	0	147	2	1.36	181	0	0	136	1	.74	.98
May 10	177	3	1.69	205	1	.48	119	2	1.68	149	0	0	151	3	1.99	1.12
May 20	174	0	0	180	0	0	181	0	0	No record			136	1	.74	.15
								Open Furrow								
March 31	170	30	17.64	173	2	1.15	175	0	0	118	0	0	150	1	.66	4.25
April 10	164	31	18.90	116	0	0	166	0	0	171	1	.58	119	3	2.52	4.75
April 20	168	20	11.90	159	0	0	174	0	0	166	0	0	114	0	0	2.59
April 30	166	17	10.24	159	3	1.68	135	0	0	192	1	.53	116	1	.86	2.86
May 10	108	31	28.70	190	0	0	117	0	0	182	0	0	129	1	.77	4.41
May 20	94	9	9.58	116	0	0	153	0	0	No record			No record			2.48
								Surface								
March 31	175	69	39.43	188	1	.53	195	0	0	76	0	0	231	3	1.30	8.44
April 10	168	75	44.64	166	0	0	188	0	0	154	3	1.83	142	4	2.81	10.12
April 20	172	22	12.77	195	2	1.03	204	0	0	169	0	0	115	4	3.48	3.28
April 30	173	12	6.93	185	0	0	173	0	0	181	0	0	120	2	1.66	1.68
May 10	164	6	3.66	199	2	1.00	158	0	0	149	0	0	151	4	2.65	1.46
May 20						.48	186	0	0	No record			125	2	1.60	1.31

liminary diggings made at Manhattan in grasslands, the writer has found that wireworms are very close to the surface during March, April, and early May.

In 1924 and 1929, the greatest injury occurred from April 10 to May 20. The desirable time for planting corn at Manhattan is from April 20 to May 10. This fact suggests the impracticability of delaying planting in order to avoid wireworm attacks.

CONTINUOUS CORN AND ROTATION PLOTS.—Observations were made for a six-year period on the continuous corn area and the plots devoted to crop rotation systems. Each of the areas were made up of a series of plots treated with commercial fertilizers or manures, but the counts for the individual plots are not included in the discussion. The records of injury on the continuous corn series and the various rotations are taken on each series as a whole.

In 1924, only the hills were counted; hence, the percentage of plants attacked would undoubtedly be lower than the seven-tenths per cent given in Table 4. For the six-year period, the greatest amount of injury occurred in 1929, when a count of ten rows, extending crosswise of the plots, totalling 3215 plants, showed an injury of 77 plants, or 2.09 per cent. The years 1925 to 1928, inclusive, showed a very low percentage of infestation.

A brief survey of Table 4 indicates clearly that corn grown on land cropped to continuous corn suffered less from wireworm damage than that grown in rotations with wheat and oats, because, in the former case, the land is kept free of other grasses and weeds except what comes up in the field after the cultivation season. The average percentage of injury to corn grown in the cowpeas after wheat rotation amounted to .74 per cent; corn, oats, alfalfa, and sorghum rotation, .75 per cent; 16-year rotation, .52 per cent as compared with .45 per cent to the continuous corn for the same period.

Since it is generally believed that click beetles select grasslands in which to deposit their eggs, the introduction of a small grain crop into the rotation increases the possibility of an infestation, provided other environmental factors are suitable to the life processes of the insect. Plots sown to wheat and oats usually become grassy after the crop is harvested and before the seed-bed is plowed in preparation for the next crop. This delay affords an opportunity for the females to deposit their eggs. The data in Table 4 also show very little difference between the amount of injury occurring on the various rotation systems.

Frequently, crop rotations are recommended as a method of control for wireworms. The writer believes that the data submitted in Table 4

TABLE 4. WIREWORM INJURY TO CORN WHEN GROWN CONTINUOUSLY AND IN ROTATIONS

	1924			1925			1926			1927			1928			1929			Per cent of Injured Plants for Six-year Period
	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	Total Plants	Injured Plants	Per cent Injured	
Continuous corn	5849	45	.7	12580	23	.18	17728	69	.38	14545	45	.31	16161	29	.18	3215	77	2.09	.46
Corn, wheat, cowpeas.	6772	38	.5	10825	35	.30	No record			No record			7352	9	.12	1229	34	2.76	.74
Corn, oats, alfalfa, sorghums	1861	14	.7	3061	17	.55	4925	39	.70	5088	51	1.00	4423	14	.34	1964	25	1.27	.75
16-year rotation, corn after wheat	5350	70	1.3	10501	31	.29	No record			14389	69	.47	No record			6277	5	.08	.52

indicate that the crops included, as well as the sequence in which one crop follows another, are important factors to be considered.

Correspondence which came to the writer's attention in this study included a report by a farmer in which he stated that wireworms attacked corn planted on land previously cropped to alfalfa for a number of years. The severest infestations occurred in low areas which had become grassy after the alfalfa had died. This report also suggests that wireworm infestations are likely to occur even though alfalfa is included in the rotation, if the sod has been allowed to become grassy before the land is plowed.

Observations were also made of wireworm injury to rye sown on land previously cropped to Sudan grass used as a pasture crop. The species involved in this instance was *Drasterius elegans* which requires but one year in which to complete its life cycle. The field had been used as a small pasture for a period of years previous to 1924, when the infestation occurred. The larvae of this click beetle were found in about equal numbers with the larvae of the southern corn root worm, *Diabrotica duodecimpunctata*. Approximately one-half of the plants on the area were injured or destroyed. There is no question but what the female click beetles had laid eggs in the Sudan grass pasture the preceding year.

Tillage Investigations and Wireworm Injury.—A preliminary study was made of 15 one-tenth acre plots, rotated in blocks of five with wheat and oats, each one year. The plots were plowed as follows: Plowed 10–12 inches deep, July 15; seven inches, July 15; three inches, July 15; seven inches, August 15; and three inches, September 15, in the preparation of the seed-bed for wheat. The wheat stubble was fall plowed in preparation of the land for corn, while the oats were sown on disked corn stubble.

No counts were made for the year 1925, while only the percentage of injury is given for 1929. Every hill was dug out of the five plots in 1929, and 2700 wireworms taken, 1000 of which were found in the plot, plowed three inches deep in September. Table 5 shows the data taken from 1926 to 1929, inclusive, on corn grown under the different tillage practices.

An examination of Table 5 shows that severe wireworm injury occurred on the five plots of the series planted to corn in 1929. The heaviest infestation was found on those plots plowed August 15, seven inches deep; and September 15, three inches deep, over the four-year period.

This study indicates that late plowing in the preparation of the seed-bed for wheat furnishes favorable conditions for female click beetles to

TABLE 5. PERCENTAGE OF INJURY TO CORN GROWN UNDER DIFFERENT TILLAGE PRACTICES

Preparation of Seed-bed for Wheat	1926 Total Plants	1926 Injured Plants	1926 Per cent Injured	1927 Total Plants	1927 Injured Plants	1927 Per cent Injured	1928 Total Plants	1928 Injured Plants	1928 Per cent Injured	1929 Total Plants	1929 Injured Plants	1929 Per cent Injured	Per cent of Injured Plants for 4-Year Period
Plowed July 15, 10–12 inches				1368	7	.51	1063	0	0	——	–	15	5.17
Plowed July 15, 7 inches....	981	46	4.7	1119	13	1.16	1124	0	0	——	–	20	6.46
Plowed July 15, 3 inches....	904	83	9.1	1089	21	1.93	1061	4	.38	——	–	25	9.10
Plowed Aug. 15, 7 inches....	1111	46	4.1	1111	29	2.61	1117	2	.18	——	–	75	20.47
Plowed Sept. 15, 3 inches....	1033	62	6.0	1086	16	1.47	1082	5	.46	——	–	99	26.73

deposit their eggs because the wheat stubble land becomes grassy and suitable for oviposition. Apparently the depth to which the land was plowed made very little difference upon the amount of injury found.

Further observations and rearing work will be necessary to determine the effect of various tillage practices upon the wireworm infestations. However, it is the opinion of the writer that tillage practices undoubtedly account for some of the wireworm infestations occurring in cultivated crops.

Summary

1. A six-year study of wireworm injury to Indian corn planted on land subjected to various farming practices conducted at this station shows that the severity of wireworm infestations is influenced by the various methods.

2. A perceptible increase in the percentage of wireworm injury was evident in the rate of planting studies when the plants were spaced 20 inches or more apart. This fact also held true for the rate and date of planting tests started in 1929, the injury being greater to corn planted on May 2 than that planted on May 18.

3. The date and method of planting plots showed a greater injury to corn planted from March 31 to May 10 at Manhattan, than that planted later. Listed corn suffered the least from wireworm injury while that planted in the open furrow and on the surface exhibited the greatest injury. There was very little difference between the percentage of injury shown between the corn planted on the surface and that in the open furrow.

4. Observations on crop rotation systems indicate that those including wheat, oats and alfalfa are conducive to wireworm infestations if the land is allowed to become grassy before preparing the seed-bed for the next year's crop. Corn planted on land cropped continuously to corn for a period of years showed less injury than that grown in rotations.

5. The time of plowing wheat and oats stubble in preparation for the following crops influenced the amount of wireworm injury occurring in corn planted on these plots. Stubble land, plowed September 15, had a greater infestation than that plowed immediately after harvest.

Literature cited

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PRESIDENT T. J. HEADLEE: We will now listen to a paper by Leonard Haseman.

THE HESSIAN FLY LARVA AND ITS METHOD OF TAKING FOOD

By LEONARD HASEMAN, *Columbia, Mo.*

ABSTRACT

The larva of the Hessian fly (*Phytophaga destructor* Say) has a perfect digestive tract similar to other fly larvae. It takes only liquid food and its mouth organs seem well fitted for taking food from the plant tissues. The oesophagus is very slender, the proventriculus well developed, joining the very large ventriculus with a typical oesophageal valve. The paired salivary glands consist of an enlarged basal part and a cylindrical distal portion. The single pair of well developed Malpighian vessels connect with the ilium immediately behind the ventriculus. The posterior portion of the ilium is much constricted and joins the expanded colon with a perfect valve. The larva appears to be well equipped physically to take food from the host wheat plants and a study of its digestive tract fails to explain why it is able to mature more successfully on one strain of wheat than on another.

To those of us who are especially interested in Hessian fly investigations and particularly to those working on the relative susceptibility of the different strains of wheat to fly infestation, the question of just how the fly maggot takes its food is of special interest. For several years the writer has been interested in undertaking a careful study of the anatomy and physiology of the fly larva, but not until recently was the opportunity offered to undertake the work. These brief remarks will deal entirely with the digestive tract of the larva. At a later date a more detailed report on its anatomy and physiology will be prepared. In this study it has been necessary to use living larvae, mounted specimens of dissected larvae, and stained microtome sections.[1]

With all that has been said and written regarding the Hessian fly it seems strange that apparently so little information on the anatomy and physiology of its larva is available. Dr. Marchal's exhaustive report, on the Cecidomyidae attacking cereals, in the Annals of the Entomological Society of France for 1897 included a somewhat detailed anatomical study of the Hessian fly larva. C. C. Hill's report on *Platygaster vernalis* Myers, an important parasite of the Hessian fly, in the Journal of Agricultural Research for 1923 also included some figures on the anatomy of the larva. The anatomy of a related species, *Cecidomyia resinicoloides*, was carefully worked out by Francis X. Williams

[1]The writer is greatly indebted to C. C. Hill of the Bureau of Entomology for the loan of the slides of microtome sections prepared by him in his parasite study.

and published in the Annals of the Entomological Society of America in 1910.

HEAD AND MOUTH.—The head of the larva, while small and retracted, is surrounded by a rather rigid ring of brown chitin, which interferes with sectioning. The mouth is literally filled with what appear to be two pairs of brown chitinous structures and a rather distinct forked structure, probably the labium. The large outer curved pair extend dorso-caudad as slender brown prongs. Fitting into the curved mesal surface of these is the second smaller pair of chitinous structures. Between these is an oval opening through which the plant sap is probably drawn. The surfaces of these paired structures are rough, or toothed, and they are undoubtedly made use of in taking sap. Dorso laterad to the mouth are the short, but distinct, antennae.

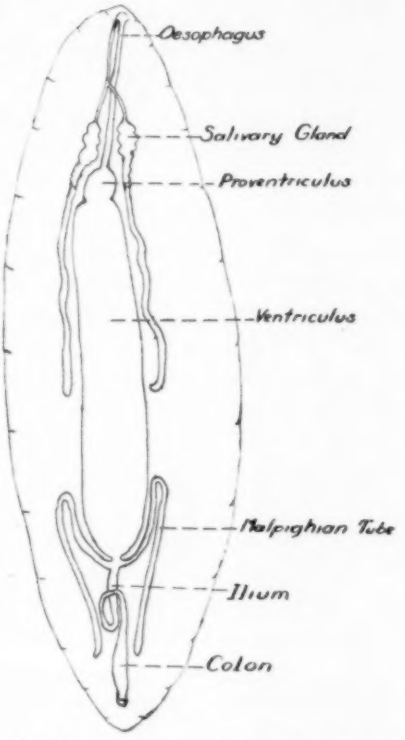


FIG. 36.—Diagram of alimentary tract of Hessian fly larva.

In the floor of the mouth the common duct of the large paired salivary glands opens. The epithelial lining in the back part of the mouth, or pharynx, consists of rather large deep-staining cells. Surrounding the pharynx and extending back halfway to the brain is a girdle of tissue, which stains deeply and which can easily be seen in the living larvae. Near the caudal end of this girdle appear two distinct oval pigment spots. It is possible that this girdle of tissue about the pharynx may function in helping to draw the plant sap into the digestive tract.

OESOPHAGUS.—The oesophagus extends caudad as a very slender tube through the brain to join the prominent proventriculus located in the fourth body segment. The epithelial cells of the oesophagus are very small and the lumen is much constricted. In cross section the oesophagus is scarcely noticeable with its lumen practically closed.

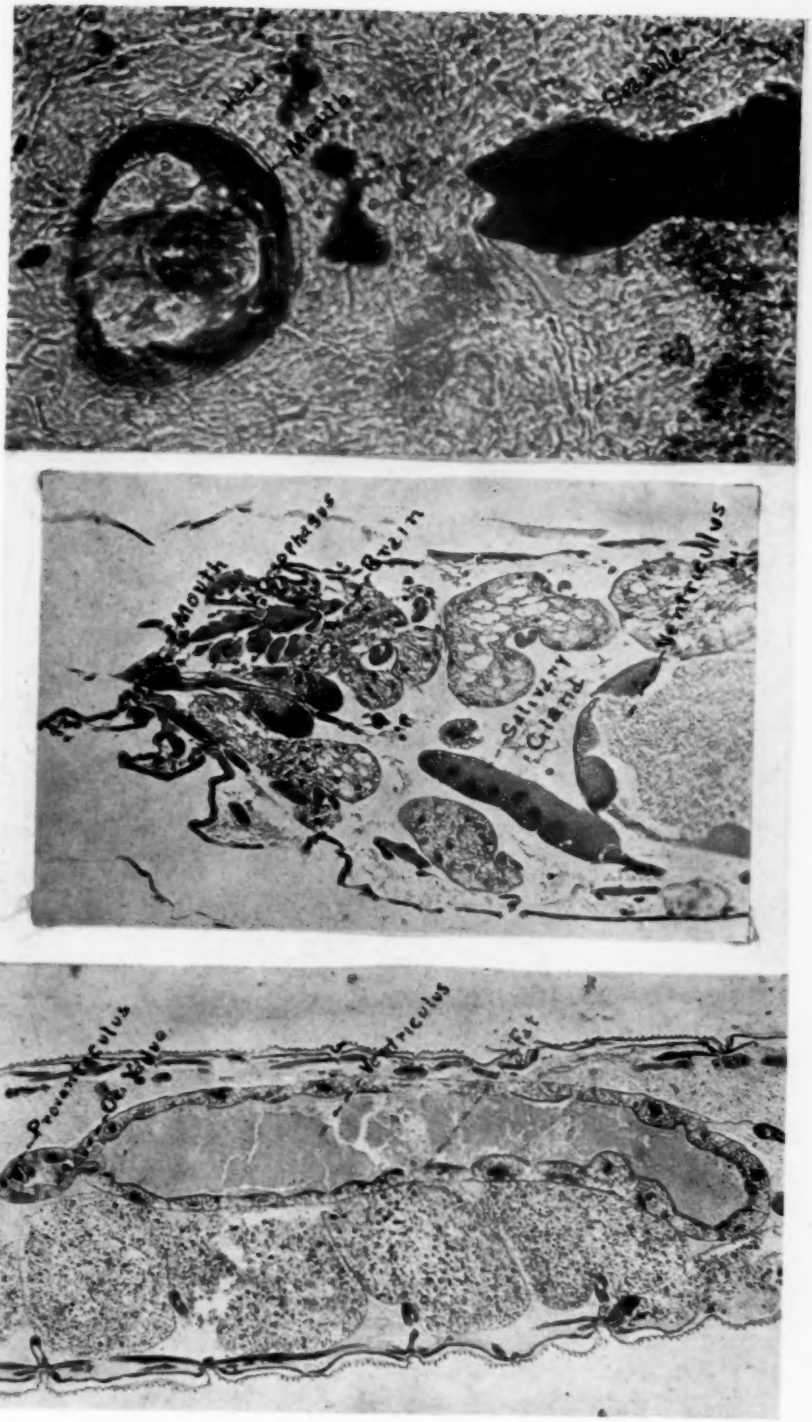
SALIVARY GLANDS.—The paired salivary glands each consists of an enlarged basal portion and a cylindrical distal portion. The common duct to the glands extends from the mouth back to a point about halfway to the brain, where it divides, a duct going to either gland. The enlarged basal portions of each gland extend from the region of the brain back to the proventriculus where the distal long cylindrical portion begins. The distal portion fits into a concavity on the caudal edge of the enlarged basal portion. The distal portion extends caudad along the side of the ventriculus to the middle of the seventh body segment. The cells of the basal portion are very large, giving to its surface an escalloped appearance. The cells of the posterior portion are smaller but with large nuclei. The lumen in this portion of the gland is distinct.

PROVENTRICULUS.—The proventriculus is slightly oblong in shape, its diameter nearly one-half that of the ventriculus. Its connection with the ventriculus forms a typical valve projecting into the ventriculus. Its epithelial cells are large with conspicuous nuclei.

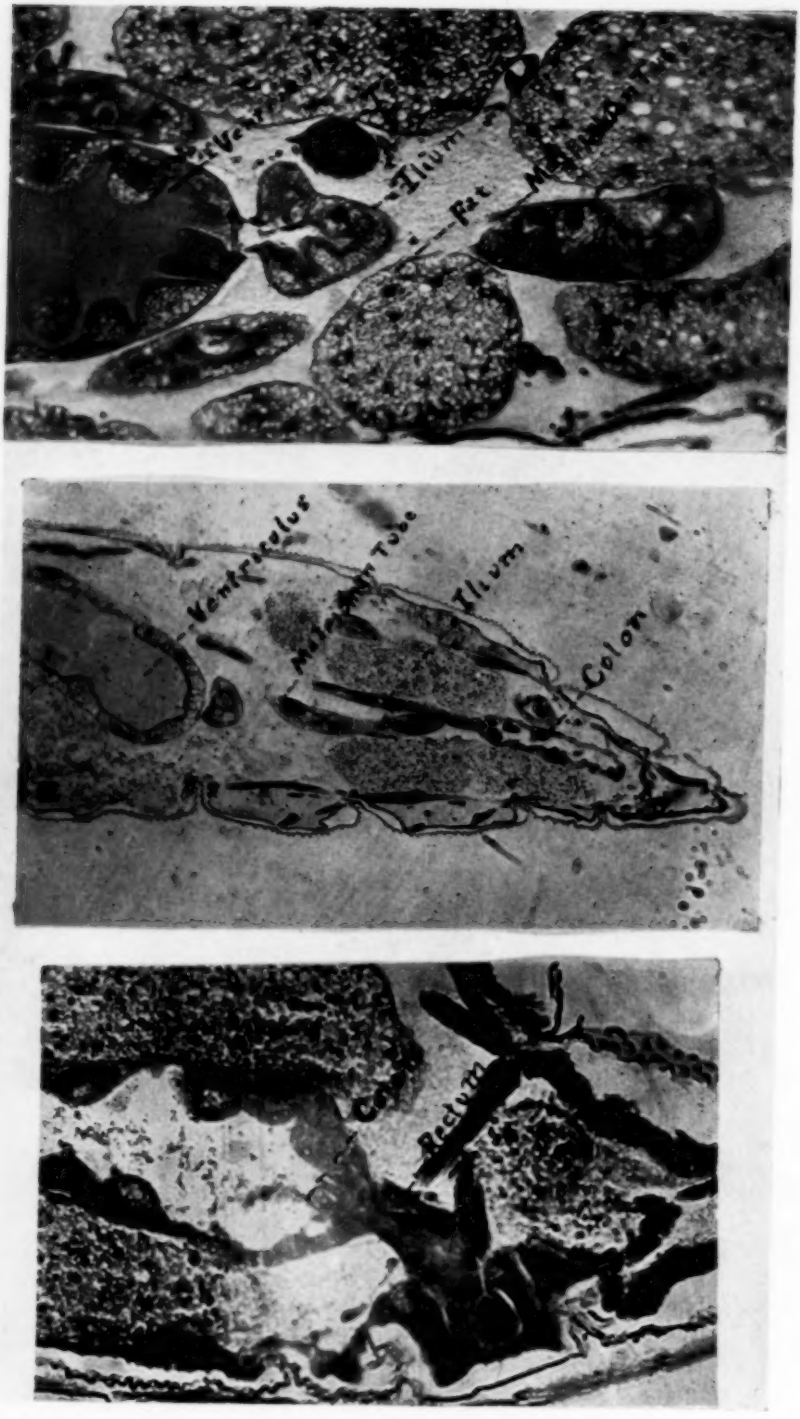
VENTRICULUS.—The most conspicuous thing about the ventriculus is its enormous size and its giant epithelial cells with their large nuclei. These cells and nuclei are so large that they can easily be seen in the living specimens, even with the low power of a compound microscope. Looking down on the surface of the ventriculus the enormous cells appear in rows. The ventriculus extends from the middle of the fourth body segment to the caudal edge of the ninth. It is cylindrical, usually stuffed with food, including a very fine green granulation, and fills practically all the space between the two lateral rows of fat-bodies. Its diameter is approximately one-eighth its length. In living specimens peristaltic action is going on practically all the time.

MALPIGHIAN VESSELS.—There is a single pair of Malpighian vessels. They connect with the ilium immediately caudad to the ventriculus. The connection is so close that they almost appear to connect with the ventriculus. They connect on the lateral surface of the ilium and each bends forward along the side of the ventriculus to a point near the middle of the eighth body segment when they turn caudad and extend back to near the middle of the colon. Their cells are large and have a brownish pigment.

ILIUM.—Where the ilium joins the ventriculus its diameter is approximately the same as that of each Malpighian vessel. The enlarged basal portion of the ilium extends back almost to the cephalic end of the enlarged colon where it turns abruptly cephalad to a point almost halfway back to the ventriculus. Here it abruptly constricts to a narrow



Hessian fly larvae anatomy shown in microtome sections.



Hessian fly larvae anatomy shown in microtome sections.

tube of about the same diameter as the oesophagus. This slender portion then turns caudad and joins the colon in the tenth body segment. The cells of the enlarged portion of the ilium resemble those of the Malpighian tubes so much that for a time sections across it were mistaken for sections of the Malpighian tubes. The epithelial cells of the slender portion are very small and their nuclei are inconspicuous. The ilium of the young larvae does not show such a marked looping. In some specimens the looping may extend back to the caudal end of the ventriculus.

The ilium, like the proventriculus, joins the colon with a distinct valve extending into the colon.

COLON.—The epithelium of the expanded colon consists of large cells with prominent nuclei. The diameter of the colon is twice that of the Malpighian tubes. It extends from its union with the ilium in the tenth body segment to the short and much constricted rectum.

The epithelial cells of the rectum are smaller than those of the colon. The anus opens on the twelfth body segment through a rather inconspicuous slit.

The larva of the Hessian fly has, therefore, a normal digestive tract closely resembling that described for other dipterous larvae. Being a feeder on sap, its mouth and oesophagus are constricted though its ventriculus is greatly expanded. Lying as it does, between the base of a leaf sheath and the stem of the wheat plant, it is in position to firmly attach its mouth with its chitinous mouth organs to the surface layer of plant cells and from them extract its food. The depression in the stem of the plant in which the fulfed larva or flaxseed is found imbedded indicates that in taking its food it eventually destroys the plant cells where it feeds. With every indication that the feeding larva is fully equipped to take plant sap from the surrounding plant cells, it would seem that ease or difficulty of the larva in taking food, once it reaches its normal feeding grounds, could not account for the susceptibility or the comparative resistance of the different strains of wheat to Hessian fly attack. The ability of the fly to mature better in one strain of wheat than in another must be due to factors other than the actual physical labor of taking food from the surrounding plant cells.

MR. E. P. FELT: May I ask the speaker whether his study led him to conclude that the mouth parts of this larva are used to abrade the tissues; furthermore, whether he has observed the function of the breastbone. Is that used in the abrading of the tissues?

Mr. L. HASEMAN: I feel rather certain that the mouth organs are used in some way in helping to get the sap from the cells. We know, of

course, that the larvae take sap, get it by some means or other, and I feel certain that this elaborate type of structure in the mouth must be used in some way in making this possible.

I haven't given any considerable thought to the "breast bone." I doubt, however, if it is used for that purpose as I find that it becomes very much more prominent after the flaxseed case is formed.

MR. E. P. FELT: I should like to supplement the question by calling attention to the fact that in some species, at least, the breast bone is evidently used as a graving tool, especially in species which live in soft wood. I have seen in the case of one which develops in the pine, the breast bone actually used as a tool in digging out considerable quantities of wood powder. This is also true of the larvae in the pith of certain herbaceous plants.

MR. L. HASEMAN: I might say that Dr. Marchal and other workers have concluded that the "breast bone" or "sternal spatula" of the Hessian fly larva is used in reversing the position of the larva in the flaxseed case. I have made no careful study of this structure as yet.

I have in the course of preparation sections of the wheat plant in the region of feeding, which will probably help me in determining to what extent, if any, the tissues are rasped by either the breast bone, if it is used for that purpose, or by the mouth organs.

MR. R. H. PAINTER: At the Kansas Agricultural Experiment Station we have been interested in the problem of the resistance of wheat varieties to attack by the Hessian fly, and in the last two or three years I have attempted to study this problem of the feeding of the larva because that is one of the main points in regard to the resistance of the wheat varieties.

In Marchal's paper of 1897, I found a good discussion of the internal anatomy of this insect. Although he is rather vague in some places in regard to the structure of the head, I may say, as Doctor Haseman has pointed out, this part is very small. In fact, you can get most of it at one time under the high power oil immersion. There are some discrepancies between Doctor Haseman's account and that given by Marchal. I am just wondering if this may not be concerned in an explanation of some of the facts which I will bring out in my paper this morning; that is to say, the presence of different strains of Hessian fly.

I have been studying the larva in situ in the plant tissue by means of sections. Probably a good many of you realize that it is a difficult thing to section both plant and animal tissue at the same time.

Perhaps I can answer the questions which Doctor Felt raised in regard to the feeding. I have been unable to find any evidence of a tearing up of the plant cells by the larvae which I have studied. There is no hole in the wall of those cells large enough to be visible under the compound microscope.

The mid-gut of the larva contains only liquid matter. There is a question in my mind as to whether the mouthparts are heavy enough or capable of piercing the cell walls of the plant. It is quite possible that they may have some influence in mechanically irritating the plant tissue. The best evidence we have concerning effect on the plant is that cells inside the plant and four or five cells away from the larvae are injured. It is probable that secretions from the insect pass to those cells, which are far beyond the reach of the mouthparts.

Frankly, the problem of feeding of the Hessian fly appears to be a matter of the permeability of the cell wall, especially at the time the larva starts feeding, and in regard to the cells at a distance from the larva.

According to Marchal's paper, and some observations I have made in this matter, the "breast bone" is not present in the feeding larvae of the Hessian fly. I should like to know whether some of the other workers have located the "breast bone" in this stage. It is present in the larva which is enclosed in the flaxseed, where, according to Marchal, it is used in reversing the position of the larva.

Vice-President F. N. Wallace assumed the Chair.

A Wild Host of *Mineola scitvlella.* A moth, *Mineola scitulella* Hulst, which Mr. Wakeland reports as doing considerable damage to apricot and prune fruits in a few parts of southern Idaho, was reared from chokecherry galls in southern Cache County during the summer of 1929. The galls caused by an ascomycete, *Plowrightia morbosa*, were very numerous on the branches and stems of the chokecherry, *Prunus melanocarpa*, in Sardine canyon and were almost invariably infested with small lepidopterous larvae. On May 15 the galls were numerous and contained larvae of different sizes. Several galls were brought into the laboratory, and on June 28 one adult, *Mineola scitulella*, emerged. Larvae of varying sizes were present on July 10, at which time another collection was made. From this material two adults of *M. scitulella* and several adults of a smaller dark brown species emerged. *Mineola scitulella* was also reared from wild plum collected at Lewiston, in northern Cache County early in the summer of 1929. The U. S. National Museum has specimens of this moth from Colorado, New Mexico, Utah, Washington, Idaho, and California.

H. J. PACK and V. DOWDLE, *Utah Agricultural Experiment Station*

VICE-PRESIDENT F. N. WALLACE: We will now hear a paper by R. H. Painter.

THE BIOLOGICAL STRAINS OF HESSIAN FLY[1]

By REGINALD H. PAINTER, *Kansas State Agricultural College*[2]

ABSTRACT

Under field conditions, some of the wheat varieties attacked by Hessian fly (*Phytophaga destructor* Say) in the soft wheat belt of southeastern Kansas, show a degree of infestation different from the same varieties under infestation in the hard wheat belt of central and western Kansas. In the latter case, for instance, Kanred wheat is susceptible to fly, while Illini Chief selection 223415 carries very little or no infestation. At Columbus (southeastern) Kansas, these two varieties were about equally susceptible. In the field, some wheat varieties are resistant in both places.

Under uniform greenhouse conditions, fly from the two regions gave infestations approximating the respective field results on these and other varieties. Fly from Ohio and Indiana gave infestations differing from those of the two Kansas sources and from each other.

Under greenhouse conditions, infestation by fly from the hard wheat belt of wheat varieties planted on a wide range of separate soil types, did not give infestation percentages varying greatly from normal for fly from this source.

Strains of fly with different infestation capacities may be selected from central Kansas fly by use of individual pairs and by mass selection. In the former case, strains have been carried through three generations without change in their infestation abilities.

It is concluded that these differences in fly population are not due primarily to ecological conditions. The data tend to show that the Hessian fly population of any one locality consists of a mixture of two or more genetically distinct strains which differ in their ability to infest various wheat varieties.

Observations in the past by a number of investigators[3] on the resistance of wheat varieties to Hessian fly attack, do not agree in all respects

[1]Contribution No. 381 from the Department of Entomology. This paper embodies some of the results obtained in the prosecution of Purnell project No. 164, the Departments of Entomology and Agronomy cooperating.

[2]Acknowledgments: I am indebted to Prof. S. C. Salmon, Dr. John H. Parker, Dr. M. C. Sewell, and Mr. I. K. Landon of the Department of Agronomy, for help on the agronomic phases of this problem, especially in respect to care of the seed, of varietal selections, and in the soil study. I am also indebted to my colleagues in the Department of Entomology, especially Prof. Geo. A. Dean and the late Prof. J. W. McColloch for many helpful suggestions. I also wish to thank Mr. C. M. Packard and Mr. R. A. Blanchard of the United States Bureau of Entomology, for collecting and sending "flaxseed" for use in some of the experiments.

[3]Discussion of literature in:

McColloch, J. W. and Salmon, S. C. Relations of kinds and varieties of grain to Hessian fly injury. Jour. Agri. Res. 12:519–527. 1918.

Packard, C. M. The Hessian fly in California. U.S.D.A. Tech. Bull. 81, 25 pp. 1928.

either as to varieties injured or in regard to amount of injury. Certain workers have even found no evidence of resistance. However, later investigators, especially in Kansas and in California, have shown quite conclusively that differences do exist in the extent of fly infestation among wheat varieties as such experiments have been conducted.

Evidence is presented here that the presence of biological or physiological strains of the Hessian fly in various parts of the country may, in part at least, explain the differences obtained by various investigators and also some other discrepancies which have arisen in the course of fly studies at the Kansas Agricultural Experiment Station. Evidence is presented along four lines, three of which are positive and one negative:

(1) FIELD OBSERVATIONS AND INFESTATION COUNTS.—In Kansas, there are two chief wheat-growing regions, an eastern soft wheat belt and a central and western hard wheat belt, separated by a rolling or even rugged pasture section known as the "Flint Hills," within which wheat is grown only in the narrow valleys. Practically all of the observations in Kansas on resistance to Hessian fly have been made in the hard wheat belt west of the Flint Hills. An extension of the research program by the Kansas stations led to the establishment in various parts of the state of uniform variety nurseries for the study of resistance to Hessian fly. The results of such studies from the nursery at Columbus, Kansas, in the southeastern corner of the state, have been distinctly at variance with previous tests in which the source of infestation was fly from central and western Kansas. A comparison of a few of the varieties is given in Table 1.

TABLE 1. FLY INFESTATION ON WHEAT VARIETIES IN DIFFERENT PARTS OF KANSAS

Variety	Selection Number, etc.	% of Tillers[1] Infested		
		Fly Nursery Manhattan, Ks. Nov., 1927	Columbus, Ks. Dec., 1928	Columbus, Ks. May, 1929
Illini Chief Sel.....	223415	1.37	12.6	34.9
Kanred.....	K2401	35.3	13.3	51.9
Dawson.....	K2564	0.0	16.8	38.5
Kawvale.....	K2593	0.0	4.0	6.7
Blackhull.....	K343	10.2	3.6	5.1

[1]The term "tiller" is applied to all branches of the wheat plant, including the first sprout. In the spring count there are included under this term, both the jointed culms and the unjointed non-fertile branches.

The 1927 infestation in the fly nursery at Manhattan may be taken as characteristic of a large number of tests which have been conducted, in which fly from western Kansas was used. It will be seen that the infestation from Columbus fly is radically different. In respect to

Dawson and Illini Chief Selection,[4] as compared to Kanred, there is almost a reversal. Since the varieties are the same, this difference must be due to ecological conditions, or to a difference in the character of the population of fly.

(2) UNIFORM GREENHOUSE TESTS.—Uniform sets of seven varieties of wheat and one variety each of rye, emmer, and spelt were exposed separately to fly from Columbus (southeastern), Kansas; central Kansas; Carpenter, Ohio; and Indianapolis, Indiana. These sets of plants were exposed in cages side by side and as nearly simultaneously as the emergence of the fly permitted. The temperature and moisture conditions in the greenhouse were reasonably constant throughout the experiments. Soil conditions were the same for all plants. The experiment was repeated for the fly from all places except Indianapolis.

TABLE 2. UNIFORM GREENHOUSE TESTS ON FLY FROM DIFFERENT PARTS OF KANSAS AND FROM OTHER STATES

Variety	Selection Number etc.	% of Tillers[1] Infested by Fly From Central Kansas	Columbus, (Southeastern) Kansas	Carpenter, Ohio	Indianapolis, Indiana
Illini Chief Sel.....	233415	0	100	75.6	45.6
Kanred.....	K2401	20.9	60	43.0	43.3
Kawvale.....	K2593	0	72.7	4.7	17.7
Blackhull.....	K343	14.8	70	22.2	30.1
Winter Rye.....		0	18	12.5	5.5
White Spring Emmer		0	90	0	10.0

[1]The term "tiller" is applied to all branches of the wheat plant, including the first sprout. In the spring count there are included under this term, both the jointed culms and the unjointed non-fertile branches.

Under these conditions, the fly from southeastern and from central Kansas gave infestations closely paralleling the results obtained in the field. The fly from Ohio and Indiana gave results differing from each other and from the two Kansas sources.

(3) SOIL TESTS.—Kanred and Tenmarq, which are susceptible to infestation by fly from central Kansas and an Illini Chief selection and Kawvale, which are resistant, were planted in pots in five kinds of soil. These included a soil deficient in silicon and calcium from southeastern Kansas, a dune sand, a heavy clay, a well manured soil, and a soil to which phosphate and lime had been added. Thus this experiment included a wide range of soils. After the plants had tillered, they were infested with fly from central Kansas. The infestation of the wheat

[4]In all places in this paper where Illini Chief is mentioned, reference is made only to selection 223415 made by the Agronomy Department. This is a head row selection from the variety. The complete history of it is to be found in records of the Agronomy Department.

varieties grown on the various soils showed some small differences, but nothing approaching the reversal of infestation which was found in the comparison of the southeastern and central Kansas fly.

(4) SELECTIVE BREEDING OF STRAINS OF HESSIAN FLY.—Individual pairs were chosen from fly from central Kansas. After mating, the females were allowed to oviposit on plants of Kanred wheat, which is susceptible to this fly, and on a selection of Illini Chief, which is resistant. From these pairs it was possible to select a number of races with ability to infest Kanred, but not Illini Chief; and a few with ability to infest both of these varieties about equally. These strains, which differ in infestation capacity, have been carried through three generations without a change in this characteristic reaction.

In approaching the problem from another angle, an attempt was made to build up an infestation on Illini Chief by a kind of mass selection. In several experiments it was found that the few "flaxseed" which developed on Illini Chief from infestations of central Kansas fly always gave about equal infestation on Kanred and Illini Chief. In other words, it is possible to select, from the normal fly population of the hard wheat belt, a group of individuals which have a different infestation ability from that population. On the other hand, fly which developed on Kanred have always given a heavy infestation on Kanred and a very small or no infestation on Illini Chief, in succeeding generations.

Observations of infestations on cooperative variety tests conducted by the Agronomy Department in various parts of the state appear to indicate that in general the soft wheats frequently are more or less resistant in the hard wheat belt, while in the soft wheat belt the varieties which are resistant are more frequently the hard wheats. These field observations give some indication that we may expect varieties to be most heavily infested where they are grown in greatest abundance.

DISCUSSION AND CONCLUSION.—The data presented here may be interpreted as indicating that the Hessian fly population of any one locality consists of a mixture of two or more strains, which differ in their ability to infest different varieties of wheat. Preliminary data from breeding experiments with these strains of fly, and extensive field and greenhouse experiments on infestation of pure lines of wheat, indicate that these biological or physiological strains of fly are genetically distinct. In at least one case, strains of fly have been selected from the Hessian fly population of central Kansas, which will infest the varieties Kanred and Illini Chief in a differential manner. It appears probable that such selections have arisen in nature.

With respect to the use of resistant varieties, two courses are open. We may develop resistant varieties which may be used alternately for periods of years in a given region, or we may attempt to synthesize the resistant qualities of several wheat varieties through hybridization and selection. In this connection it may be noted that under natural field conditions in both central and southern Kansas, certain varieties show resistance to more than one strain of fly. Thus Kawvale shows considerable resistance to fly from both eastern and central Kansas, and Blackhull is less susceptible than Kanred to fly from both the hard and soft wheat sections.

VICE-PRESIDENT F. N. WALLACE: The next paper is also by R. H. Painter.

OBSERVATIONS ON THE BIOLOGY OF THE HESSIAN FLY[1]

By REGINALD H. PAINTER, *Kansas State Agricultural College*

ABSTRACT.

By following the individual histories of eggs of Hessian fly (*Phytophaga destructor* Say) laid on different leaves, it is shown that no flaxseed survive from eggs laid on the outer (1st leaf); 6.35 per cent survive from eggs laid on the 2nd leaf; and 45.4 per cent survive from those on the 3rd (central)leaf. This decrease in survival on the different leaves is paralleled by the increase in deposition of cellulose or perhaps with some condition arising with it. These facts are of interest in connection with the resistance of certain cereals to the attack of Hessian fly.

The progeny from isolated single pairs of fly were predominately of one sex. Out of 13 matings, four gave all males; five all females, and four with offspring predominately of one sex. In one case, 74 females and no males were reared from one pair.

SURVIVAL OF HESSIAN FLY FROM EGGS LAID ON VARIOUS LEAVES OF WHEAT.—In connection with the detailed studies of Hessian fly during the isolation of biological strains, certain life history observations were made which do not seem to have been reported in the literature. The numbers of flaxseed resulting from eggs laid on different leaves of the plant have been recorded with the results given in Table 1.

TABLE 1. SURVIVAL OF HESSIAN FLY FROM EGGS LAID ON VARIOUS LEAVES OF WHEAT

	On Leaves of Kanred			On All Leaves of All Varieties
	1st Leaf	2nd Leaf	3rd Leaf Central	Total
Number of Eggs	45	73	271	2017
Number of Flaxseed	0	5	123	376
Per cent Survival	0	6.35	45.4	19.8

[1]Contribution No. 380 from the Department of Entomology. This paper embodies some of the results obtained in the prosecution of Purnell project No. 164, the Departments of Entomology and Agronomy cooperating.

The Hessian fly females were allowed to oviposit on a certain number of wheat plants possessing only three leaves. The positions of the eggs were recorded. After the formation of flaxseed, the plants were carefully dissected to determine the location of these puparia with respect to the different leaf sheaths. The first three columns in Table 1 give the results for Hessian fly from the hard wheat belt of Kansas on Kanred wheat. The fourth column gives the total eggs and flaxseed for several strains of fly and the several varieties of wheat studied in this problem. Results have been used only in those cases where some flaxseed were formed on the plant under observation. A comparison of the percentage of survival of eggs laid on the third leaf with the total survival of all flies studied shows that there is a mortality of about 25% due to the position of the eggs on the plant.

The marked decrease in percentage survival from the central leaf outward is paralleled by the increase in deposition of cellulose[2] in the cell walls of the wheat c[illegible] where the larvae must begin feeding. The inability to commence feeding on the outer leaves, hence, may be due to the presence of cellulose or to some condition arising with it. With

TABLE 2. SEX OF HESSIAN FLY FROM SINGLE PAIRS

Mating Number	Number Flaxseed	Emergence	
		Male	Female
17	20	16	0
20	42	13	2
37	47	1	34
38	104*	42	6
40	21	0	9
42	20	14	0
45	20	10	3
46	39	0	18
57	88*	36	0
59	134†	0	74
67	60*	0	20
70	53	0	29
R8	32	16	0
Totals		148	195

*Many small not viable.
†39 flaxseed were very small.

some wheat varieties, this fact is of no importance in most resistance studies, as the resistant varieties, when infested, show data paralleling that given for Kanred. In the case of some other varieties, such as

[2]Cellulose was identified by means of polarized light. In the meristem tissue, especially of the epidermis, only two cell wall substances have been shown to be present in most cases. The pectic materials of the primary cell wall show dark under polarized light, the cellulose material appears bright. Other tests are being used as a check in future work, but in this particular tissue, polarized light is most useful for a preliminary study.

Blackhull and Red Winter (Kansas 2132) which give a medium infestation, an early development of cellulose may be of considerable importance, It may be a factor in the spring generation of fly on early maturing wheat varieties and in accounting for the noninfestation of some of the other cereals, such as oats.

SEX RATIOS.—In attempting to secure a strain of Hessian fly from a single pair with known food habits and infestation capacity, an unexpected difficulty was encountered. The progeny of each single pair consisted predominantly or entirely of a single sex. The sex of progeny from some of the pairs is given in Table 2.

A number of other matings in which fewer than ten adults emerged gave similar results. It will be noticed that nine out of the thirteen matings gave either males or females, but not both. In none of the others is there an approach to the normal 1:1 sex ratio of other animals or to the 40–60 female ratio of the total and of the general run of material collected in the field and bred in the laboratory.[3] The result is not due to a possible differential death rate between the sexes as in two experiments conducted side by side, one will give all females, the other all males. It is not due to hybridity between biological strains because some of the data come from strains inbred for two or three generations of flies from one locality. In the related genus *Oligarces*, male-producing and female-producing strains have been demonstrated.[4] In the case cited, parthenogenesis with its attendant cytological modifications is involved while in the Hessian fly this abnormal development has not been demonstrated by previous workers and does not appear in my own experiments. The sex ratio here is similar to that studied by Metz[5] in Sciara where he finds that females may be male-producing or female-producing, but not both, and that there is probably a selective elimination of sperm in the female.

In economic entomology, these facts must be taken into consideration in breeding work. Moreover, on account of the production of progeny of a single sex, the migration of single females is of reduced importance.

[3]McColloch, J. W. The Hessian fly in Kansas. Kansas Agricultural Experiment Station. Tech. Bul. 11, p. 38. 1923.

[4]Harris, R. G. Sex of Adult Cecidomyidae (Oligarces sp.) arising from larvae produced by paedogenesis. Psyche 31:148–154.

[5]Metz, Charles W. 1929. Evidence that "Unisexual" progenies in Sciara are due to selective elimination of gametes (sperms). The American Naturalist 63:214–228. Other references to his previous paper are given in the bibliography.

VICE-PRESIDENT F. N. WALLACE: We will now pass to a paper by G. I. Reeves.

TRANSPORTATION OF THE ALFALFA WEEVIL BY RAILWAY CARS

By GEO. I. REEVES, *U. S. Bureau of Entomology*

ABSTRACT

Recent study of the occurrence of the alfalfa weevil *Phytonomus posticus*, in alfalfa meal and meal mills, as well as of its travel in freight cars, loaded and empty, casts grave doubt upon the efficacy of certain well-established methods of preventing the spread of the species. This investigation also suggests that measures designed to prevent the spread of pests ought to be tested by the same rigid scientific standards as are applied to field control methods, but with a technique adapted to the detection of vanishingly small numbers.

Although the alfalfa weevil has been present in the United States certainly since 1905, and probably much longer, there has hitherto been no body of facts available as to the methods by which it travels from place to place and invades new territory. There have indeed been scattered observations upon its occurrence on passenger trains and automobiles, as well as in various farm products, but the principal quantitative studies of its abundance have been of an order more suitable for use in field control than in the prevention of its spread.

The abundance and the persistence of weevils in alfalfa hay, at alfalfa-meal mills and in railroad cars have recently been minutely studied with a view to the detection of such small numbers of the insects as would be negligible in ordinary dealings with crop pests, although they might be decidedly significant as a feature of the dissemination of the species. Thus, the weevil population in a field may be of the order of 87 millions per acre, and the poisoning of five-sixths of that number may ensure fairly complete protection of the crop, under which circumstances a weevil population of 14 millions per acre might be considered economically insignificant. A much lower infestation might be serious in other species and upon other host plants. This would still, however, greatly exceed the numbers which must be guarded against in an effort to keep the pest out of uninfested territory. The study of the occurrence of the alfalfa weevil in alfalfa meal, meal mills and freight cars was accordingly planned to determine the number of weevils present in the square inch of ground or floor space and in the cubic inch of chaff and alfalfa meal, rather than the number to the acre of alfalfa.

EXAMINATION OF MILLS.—Every step in the cutting, handling, stacking, hauling, and milling of the three annual cuttings of hay, as well as of an additional preliminary cutting, was observed with reference to its eliminating effect upon the weevils. One mill was kept under observation throughout October, 1928, when the whole summer's accumulation of weevils, if any accummulation occurred, was present, and during which month more than 900 tons of hay passed through the mill. At this time the weevils were active and the weather was warmer than during the oviposition period of the weevil at Salt Lake, Utah. Ninety-five thousand cubic inches of hay, meal and litter, together with 126,640 square feet of floor, ground, wall and machine surface were examined. This consumed 140 hours of time.

Another mill was watched throughout June, August, September, November and December. The examination covered 79,627 cubic inches of material and 7,411 square feet of surface, and it required 155 hours.

RESULTS OBTAINED.—In one of these mills were found 24, and in the other 20, living weevils, all in the receiving rooms and none of them in the finished product or the shipping-rooms of the mills. This record of finding one weevil to each 5.8 hours of search in the one mill and to each 7.75 hours in the other indicates the entire absence of the much-discussed tendency of weevils to accumulate at mills. Incidentally, it also establishes 6¾ hours as the minimum period for examination of mill premises to determine freedom from alfalfa weevils, even in the case of men of such extraordinary experience as those involved in this instance. No other examination of similar thoroughness has been recorded.

Since the weevils naturally present in hay upon its entrance to the grinder were so few as to make their recovery from the product impossible, 5,300 weevils were artificially added and the meal was searched bit by bit for their remains.

In addition to the field, haystack and mill survey which has been described, examinations were made of 130 cars from which hay had been unloaded. These contained, on the average, 34,872 cu. in. of chaff, of which 2,636 cu. in. were examined. One car in which all floor chaff was examined contained a total of 14,238 cu. in. of such chaff, in which were found 66 living weevils. The work required 9½ hours. These cars were then traced, with the assistance of railroad companies, for 60 days following their examination. Selected cars were also loaded with live alfalfa weevils and shipped across the weevil-infested territory, after which they were dismantled and thoroughly searched for weevils. The economic importance of this study, as suggested by the title, lies

almost entirely in the results of this car examination, the rest being merely the negation of most of the assumptions which have been made in attempts to prevent the spread of this insect. In technical interest, however, the car examination and history is merely an item in a somewhat unusual treatment of pest control.

These studies showed that relatively few of the weevils which are so abundantly present in the fields ever reach the stack, that those which do so perish for the most part before the hay is removed from the stack, that baling kills most of the remainder, and that a properly constructed and properly managed mill destroys the rest. Beyond that point, however, security ends. Cars which have been used for infested hay—and over 2,000 cars are so used each year—disperse rapidly into every corner of the United States. U. P. car 137680, in which one living weevil was found, moved empty into the Pacific Northwest in seven days and was in New York City on the 60th day after examination. U. P. car 10151, in which one weevil was found at the mill and two weevils two days later in the freight yards, reached Colton, California, 12 days after the initial examination. M. P. car 85485, in which 66 weevils were found, moved empty to Albany, Ore., not far from the new infestation at Medford, and arrived there within 17 days. In the light of experiments showing that 15 per cent of the weevils remain alive in the car during a five-day trip, and 40 per cent of them during a three-day trip, these car histories are ominous. It is believed that similar researches upon the means of travel of other insects might be equally productive.

VICE-PRESIDENT F. N. WALLACE: The next paper is by H. H. Knight.

"ALFALFA PLANT-BUG," A COMMON NAME FOR AN INTRODUCED EUROPEAN BUG (*ADELPHOCORIS LINEOLATUS* GOEZE) FOUND IN IOWA (HEMIPTERA, MIRIDAE)[1]

By HARRY H. KNIGHT, *Ames, Iowa*

ABSTRACT

The first specimens of an European plant bug (*Adelphocoris lineolatus*) found in the United States were taken at Ames, Iowa, June 18, 1929. It was previously known from North America only from Cape Breton Island. Extensive scouting shows that the bug was breeding over a limited area only with Ames and Des Moines near the center of distribution. It appears to be a clear case of accidental introduction within the past three or four years. In Iowa it has been found breeding only on alfalfa and sweet clover but in such numbers that it suggests the possibility of becoming a pest. The common name "Alfalfa plant-bug" is proposed for this insect.

[1]Contribution from the Department of Zoology and Entomology, Iowa State College, Ames.

While conducting a field trip with a class in general entomology, June 18, 1929, at Ames, Iowa, the writer took in his collecting net the first specimen of *Adelphocoris lineolatus* Goeze known from the United States. This species was previously known from North America, but only from Cape Breton Island when the writer recorded it in 1922 (Can. Ent., liii, p. 287). It was indeed a great surprise to look into my collecting net and see this large plant bug running about for the first time, and to realize that I was actually collecting in Iowa. Additional sweeping at the same spot netted only four more specimens. I thought the species must be scarce since considerable sweeping over the same area did not produce more specimens. This apparent scarcity was later explained after learning the host plants of the bug. There was only one sweet clover plant in the vicinity and this had doubtless produced all the specimens.

A few days later, June 30 to be exact, Mr. R. L. Preston, one of my students, took two specimens of *lineolatus* Goeze along a road just south of Ames. On July 2 we made a special trip to this point to search for the unusual Mirid. I soon began taking one or two specimens with each dozen sweeps of the net. Within half an hour I found that most of the adults and many nymphs were to be found on alfalfa and sweet clover which grew along the roadway. Further collecting has shown that *lineolatus* Goeze is breeding in large numbers on both these plants, and nymphs are rare if not absent on other plants. During July the bug was found in such numbers on alfalfa and sweet clover that it suggests the possibility of becoming a pest on these important plants. In some fields a dozen bugs could be taken on a single large plant; and in such places *lineolatus* Goeze was more abundant than the tarnished plant bug (*Lygus pratensis oblineatus* Say). In view of these facts the writer takes occasion to propose the common name "Alfalfa plant-bug" for *Adelphocoris lineolatus* Goeze.

In Europe *A. lineolatus* Goeze has been reported as found on *Chenopodium*, *Trifolium*, *Leguminosae*, *Umbelliferae*, *Eryngium*, *Carduus*, *Salvia*, *Euphorbia*, and *Calluna*. Fallen (1807) described our bug as new under the name *Lygaeus chenopodii*, indicating what he took to be the host plant. As yet we have not found it breeding on *Chenopodium* in Iowa.

The question of when and where *Adelphocoris lineolatus* Goeze was introduced into Iowa is a point which will become of more interest as time passes and the bug is found in adjoining states. Mr. R. L. Preston is making a survey of its distribution while working on the life history of the species and will report his results at some future time.

Just now it seems rather certain that the point of introduction was at Ames or Des Moines, with Ames more nearly the center of distribution as found by Mr. Preston. How long it has taken this insect to attain its present abundance and distribution is a question of interest to us. No specimens were taken in 1928, yet the writer and several students did fully as much collecting in this area that summer. During July many specimens of *lineolatus* were taken about electric lights on the campus; also we have found it very abundant in fields of alfalfa and sweet clover. The species has certainly increased greatly in numbers since the summer of 1928, or we most certainly would have found it then. A guess is not worth much but I would suggest that the species must have gotten its start from three to five years ago. Mr. Preston has taken specimens over an area of about 75 miles from south to north with Ames about the center of distribution.

Should this insect develop into a pest on alfalfa as it gives some promise, it will become of wide interest and concern. In any case it represents the introduction and spread of an exotic species, and as a biological problem, will interest many students of entomology. No doubt the species was imported into Iowa in the egg stage which could easily happen if parts of the host plant were used as packing in some shipment of material from Europe. Just what materials have been shipped into our area is a matter we hope to investigate as opportunity permits.

It is hoped that this notice may stimulate collectors in the states bordering on Iowa and that some may sweep alfalfa and sweet clover during the next two or three years and report the occurrence and spread of *Adelphocoris lineolatus* Goeze.

As an aid for recognition of the species the following general description is given:

MALE. Length 8 mm., width 2.8 mm. General coloration pale yellowish with a tinge of brown and dusky; scutellum with two fine, longitudinal fuscous marks on middle, corium usually with a triangular fuscous area on apical half, cuneus pale, membrane fuscous. Antennae yellowish to brown, apical half darker and usually reddish brown. Legs yellowish, femora with many black dots, anterior aspect with two rows of somewhat larger spots; tibial spines black, without distinct spots at base. Clothed in simple, pale yellowish pubescence, but black on the legs.

Head: width 1.36 mm., vertex .42 mm. Antennae: segment I, length .98 mm.; II, 2.87 mm.; III, 2.2 mm.; IV, 1.3 mm. Pronotum: length 1.3 mm., width at base 2.25 mm.

FEMALE. Length 7.5 mm., width 2.9 mm. More robust than the male and usually somewhat paler in color, but otherwise very similar in form and coloration.

NYMPH, FIFTH INSTAR. Length 5.5 mm., width 2.4 mm. Head: width 1.17 mm., vertex .52 mm. Antennae: segment I, length .73 mm.; II, 2.3 mm.; III, 2 mm.;

IV, .85 mm. Color uniformly yellowish green, third and fourth antennal segments reddish brown, tips of wing pads becoming fuscous. Legs uniformly pale yellowish and marked with black spots as in the adult. Dorsum and legs set with short stiff black hairs; antennae clothed with black pubescence.

Size slightly larger than *Adelphocoris rapidus* Say, but easily distinguished by the paler color. The general habits and actions of *lineolatus* Goeze are very similar to our native species, but it runs about in the net even more swiftly than *rapidus* Say.

PRESIDENT T. J. HEADLEE resumed the Chair.

PRESIDENT T. J. HEADLEE: The next paper is by J. H. Bigger.

NOTES ON THE LIFE HISTORY OF THE CLOVER ROOT CURCULIO, *SITONA HISPIDULA* FAB., IN CENTRAL ILLINOIS[1]

By J. H. BIGGER, *Illinois Natural History Survey*

ABSTRACT

The Clover Root Curculio, *Sitona hispidula* Fabr., is a potentially serious pest of clovers and alfalfa. Adults hibernate and oviposit both fall and spring. Eggs hatch in the spring. Larvae feed for 21–27 days on the nodules and small roots of the food plants. Pupation occurs mostly in June and requires 17–22 days. It is at approximately the time of first cutting of alfalfa for hay. Adults emerge during June and July and live practically an entire year.

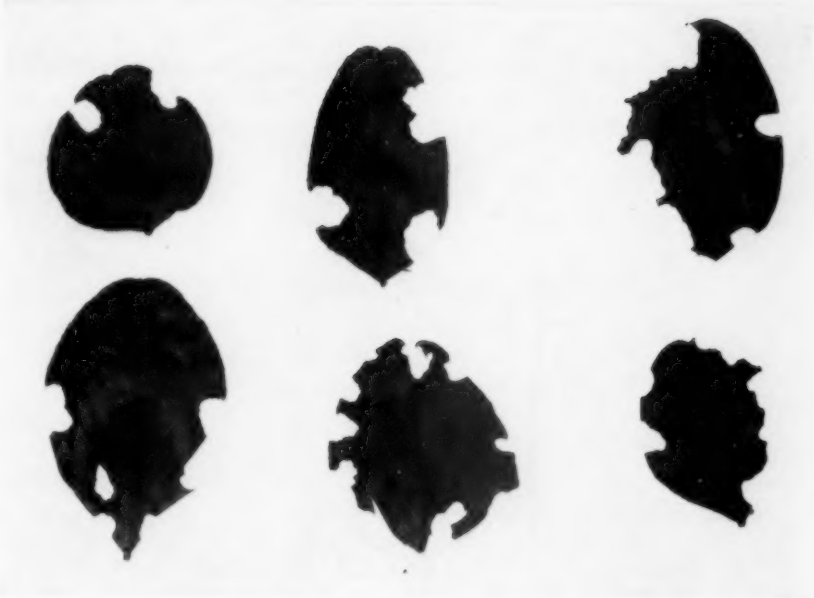
The Clover Root Curculio, *Sitona hispidula* Fab.[2] has attracted very little attention up to the present time. During the course of a general study of clover insects in central Illinois it became apparent that this insect is a potential pest of clovers and alfalfa of considerable importance. These observations were made in 1923 and, as a result, during the fall of 1924 a study of its life history was started. Available time during the first season was occupied in developing a technic and becoming better acquainted with the insect. The most important records were obtained during the seasons of 1925–1926 and 1926–1927.

DAMAGE

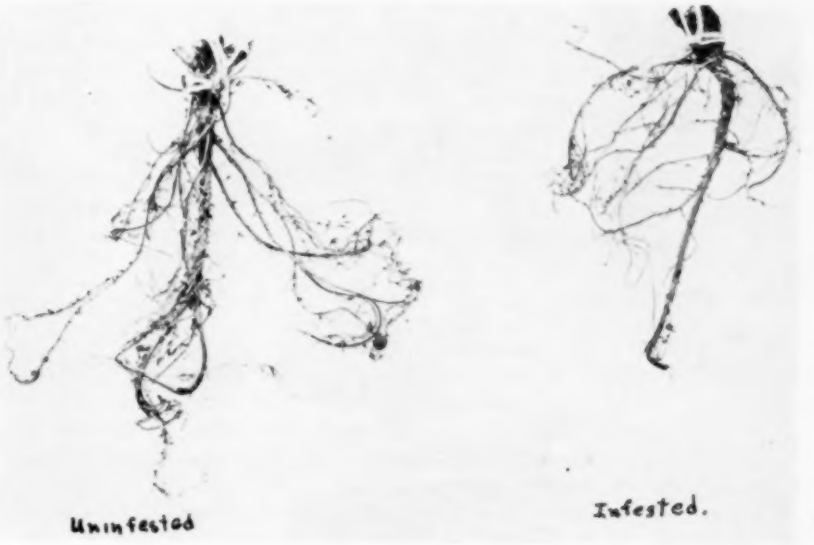
The adults feed at the edges of the leaves, standing astride the edge and making typical rounded cuts in them. (Plate 14) Damage is usually not severe in this section, though we have one case on record

[1]Project 1.4 of the Entomological Section of the Illinois Natural History Survey.

[2]Identity checked by Dr. T. H. Frison and verified by Mr. C. A. Frost of Framingham, Mass. Mr. Frost wrote that specimens of this form had been submitted to Mr. Charles Drury, and determined by the latter as *S. hispidula*.



Feeding by adults of *Sitona hispidula* Fab. Each leaf fed on by one pair during 2-day period in November 1927.



Feeding by larvae of *Sitona hispidula* Fab. Right—Infested. Left—Uninfested. Dug June 10, 1927

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where adults migrating from a recently plowed red clover field destroyed a half-acre of newly sown alfalfa in a few days. The migration was stopped or it is likely that the entire 10 acres in the alfalfa field would have been destroyed. In cages one pair have been known to consume a red clover leaf 30 mm. long and 15 mm. wide in four days. See also the report by Wiedermuth (4).

Larval feeding is the most serious part of the damage done to clover and alfalfa. It is all the more serious in that it is not seen in more than the minimum of cases, nor recognized when it is seen. The larval feeding (Plate 14) occurs first on the nodules, then the smaller roots, and finally on the main root system. In many cases roots have been dug where all the nodules and most of the smaller roots have been removed by this insect. They are frequently very numerous in the fields. One rather heavily infested field in Morgan county, Illinois, was examined May 18, 1927 and found to have 36, 43, 33, 41, 39, and 37 larvae respectively in square foot areas at different points in the field.

Descriptions

Adult. The adult of the Clover Root Curiculo, *Sitona hispidula* Fab., is a small weevil 3.5–5 mm. long. The pronotum is about 2 mm. wide at the middle and tapers both ways. The elytra are about 2 mm. wide at the base tapering slightly and rounded at the posterior end, about twice as long as the prothorax. (A technical description is given in Blatchley and Leng (1)). The general body color is black sometimes shading to dark brown or brick red. The ventral surface is ash-gray and thickly clothed with fine hairs. The elytra are covered with short, pitted, gray or brownish scales in distinct rows and rather thickly clothed with short, recurved hairs. In the centre and on both sides of the pronotum are indistinct, brown or gray, somewhat irregular lines. The beak is short, curved and thick, being nearly as wide as the thorax at its base and thickly clothed with hairs. The antennae are reddish, longer than the beak, but folding into it so as to be inconspicuous.

Egg. The egg is ellipsoid, nearly round, and slightly granular, .36 mm. in diameter. When first laid it is a light yellow color but in a few days it turns to a dusky black. The length of time required for this change varies inversely with the amount of moisture present. An average length of time required for the change is about 3 days.

Larva. The larva is a small, white, fleshy grub about .7 mm. long when first hatched, with prominent light-brown head. It is roughly rectangular, not tapering very much to the posterior end, which is broadly rounded. When full-grown the larva is about 5 mm. long, broad, heavy, and sluggish. It lies curved in a crescent shape when removed from its food plant.

Pupa. The pupa is white, sometimes with a slight yellow tinge, 4 mm. long, found curled in an oval cell about 5 mm. in diameter at a depth of ½–1 inch below the surface of the soil. (See also report by Webster (3)). The abdomen tapers gradually toward the posterior end on which are two prominent rather dark curved spines. After a few day's growth the eyes and later the beak turn brown, and finally, just prior to emergence the whole body is gray with yellow legs.

Methods of Procedure

Adults were collected in the field for all experimental work. To obtain egg records pairs were enclosed in glass or celluloid tubes about 1¼ inches in diameter and 6 inches long. The tubes were set in the ground, filled with soil to the ground level, and stoppered with cotton. The adults were fed on red clover or alfalfa leaves. The tubes were set among the plants in a clover field so as to be shaded part of the time. For general observations and habit studies five pairs were enclosed in each of a number of cylindrical wire mesh cages about six inches in diameter and 15 inches high, or 50 pairs were enclosed in wire mesh cages about 2 feet square and 18 inches high. Eggs for hatching records were taken from tubes that had been cleaned not more than 24 hours previous so that none were more than one day old at the start.

Larvae for the studies were collected in the field to some extent, but were obtained mostly by putting eggs from the oviposition tubes into a series of wire mesh cages over individual seedling red clover plants. Information regarding the length of the larval and pupal periods was obtained by digging and examining these plants at regular intervals. At first some were dug every day, but after a number of trials it was possible to make these examinations within a few days of when hatching of eggs or pupation of larvae was to be expected.

Life History

Adult. Adults are present in the field practically the entire year. In some seasons emergence has been observed as early as June 8th, other seasons it may be delayed until the first week in July. They are active until continuous hot weather sets in and are then inactive until early fall. During the first part of September active feeding commences, continues until freezing weather, and occurs during warm periods of the late fall and winter. Activity is renewed in the spring during the latter part of March and continues until death. Many adults die during the winter but the period of greatest mortality is after May 1st. Some may be found in the fields until the first or even the middle of June in a cool season. In general adults are most active when temperatures are between 50 and 75 degrees F. and oviposition is most general at that time, though eggs have been observed deposited with temperatures around 40 degrees F. They feed actively when first emerged and during oviposition periods.

Mating starts about the middle or third week in September and occurs during all active periods until death. It is promiscuous. In

several cases the males died during the course of the experimental work. When new males were supplied mating and oviposition proceeded as before.

The adults were able to undergo submergence in water for at least 24 hours and survive. This happened in a few cases during the course of the work. Several times they were frozen in solid ice and resumed activity when thawed out.

They seldom fly, but are capable of flights of considerable distances, having been collected on wheat at least a half-mile from the nearest clover. We have been unable to make them feed on wheat.

EGG. Oviposition commences in central Illinois generally about the middle of October, continues to the last of November or first of December, occurs occasionally during the winter, starts up again about the last of March and continues until the adults die. Occasionally eggs are found as early as the first of October. Fall oviposition by this species has also been reported from England (2).

The eggs are laid usually on the soil at the base of plants or under trash, or on the stems of plants and stipules of leaves, and have been found on grass in our cages. Both cage and field records show 80–90 per cent of them on the soil. They are laid both night and day. This was determined by removing the eggs from our oviposition tubes twice a day during four periods, both at sunset and soon after daybreak in the morning.

A long series of tests show the times and numbers of eggs laid. For brevity they have been reduced to the following table.

The records for 1925–1926 are for the same adults kept in the cages continuously from start of fall observations until death in the spring. The project started with 50 cages. Included in the records are only those that survived the winter and lived until at least April 29th. The cages were covered with straw December 15th and uncovered the last of February. During the 1926–1927 season we gave the cages no cover in order to observe the effect of exposure and winter habits. None survived after February 28, 1927. They were replaced early in March. The table shows the records of the original and replacement adults. Having once carried them through and knowing that they survive in freedom, we considered this fair. Again only those that lived until April 23rd were included in the record.

These records for the 1925-1926 season show that the 25 females laid a total of 3469 eggs during a laying period of about 92 days, an average of 139 eggs per female of 1.5 eggs per female per day. They show that 918 of these eggs were laid during the fall season and 2551

TABLE 1. RECORD OF OVIPOSITION OF *Sitona hispidula* FAB. IN ILLINOIS 1925–1927

	Number Females	Start Oviposition	Finish Oviposition	Number Days in Oviposition Period			Total Numbers Eggs Deposited	Seasonal Percentages	Number of Eggs per Female			Average Number Eggs per Day	Maximum Number Eggs per Day
				Maximum	Minimum	Average			Maximum	Minimum	Average		
Fall 1925	25	Oct. 12	Nov. 30	49	25	41.12	918	26.4	72	8	36.72	.89	9
Spring 1926	25	Mar. 19	May 31	74	32	50.60	2551	73.5	228	25	102.04	2.01	13
Total for Season[1]	25	Oct. 12	May 31	123	65	91.72	3469		269	33	138.76	1.51	13
Fall 1926	34	Oct. 14	Dec. 13	47	1	38.26	1565	27.5	113	1	46.02	1.20	12
Spring 1927	34	Mar. 28	June 7	69	4	45.44	4106	72.4	277	4	120.76	2.65	18
Total for Season[2]	34	Oct. 14	June 7	108	26	83.70	5671		365	15	166.79	1.99	18

[1]Same females throughout.
[2]Females replaced (see text, p. 000).

during the spring season, or 26.4 per cent during the fall and 73.5 per cent during the spring season.

The records for the 1926–1927 season show that a total of 5671 eggs were laid by 34 females during total laying period of about 84 days, an average of 167 eggs per female or two eggs per female per day. They show that 1565 of these eggs were laid during the fall and 4106 during the spring seasons or 27.5 per cent during the fall and 72.4 per cent during the spring seasons.

Eggs were not laid by each female every day during the laying period but a record of the days during which each did deposit eggs would be too cumbersome for the purpose of this paper.

These records were supported by field observations. To quote a few: Eggs were observed in the fields December 14, 1925, February 8, 1926, October 13, 1926, January 8, 1927, February 17, 23 and 24, 1927 and March 13, 16 and 26, 1927.

HATCHING. No eggs have been found to hatch in the fall, but eggs laid in the fall as well as eggs laid in the spring will hatch in the spring. Eggs were placed on 10 curculio-free alfalfa plants October 26, 1925. Several of these plants were dug April 19, 1926 and no larvae found. The other plants were dug May 1, 1926 and tiny larvae were found at that time.

Eggs were placed on three plants in the insectary October 26, 1926. Two of these plants were dug November 26, and no larvae were found. One larva and one pupa were found on the other plant when it was dug June 10, 1927. Our records show several other similar cases which will not be quoted here.

Fall-laid eggs require 138–200 days to hatch. The first hatching was observed May 1, 1926. In this case the eggs had lain on the soil or in the soil of a cage 139–200 days, depending on the date of laying. Hatching in 1927 was started at approximately the same date. In that case eggs required 138–192 days to hatch.

Eggs laid in the spring require 17–21 days to hatch early in the season, and 15–16 days to hatch late in the season. In the spring of 1926 eggs from oviposition tubes were placed on clean caged plants for hatching. From these larvae were found to have hatched 16–18 or 19 days later. In April, 1927 eggs were brought into the laboratory, placed on petri dishes lined with plaster-paris, and kept slightly moist in a temperature of 65–70 degrees F. Five lots of 20 eggs each were kept in this manner. In three cases the eggs hatched in 17 days, in one case 18 days, and in one case dead larvae were found that had hatched during an absence but were found 22 days after oviposition.

Eggs were placed on seedling red clover plants in the insectary from April 30 to May 21, 1927. The plants were dug at various intervals. Hatching was found to require 15–16 days.

LARVA. The larvae may be found in the soil of clover and alfalfa fields from 1 to 6 inches deep between the first of May and the middle of June during most seasons in the latitude of central Illinois. At the latter time many larvae may be expected to be in cells close to the soil surface ready to pupate. During the four years of observations no larvae have been found during the fall season. Immediately upon hatching the larvae enter the soil and begin feeding on the nodules of legume plants. Very young larvae were invariably found inside the nodules during the course of our studies. Larvae 1–2 mm. long are usually found with their heads inside a nodule on which they are feeding. Later the small roots are fed upon and operations are gradually extended until, when they are full grown they are sometimes found on the tap root burrowing and gouging irregular holes in it. This tap root feeding has been observed very few times during the period of our studies in Illinois.

LENGTH OF LARVAL PERIOD. In the spring of 1926 larvae were making cells for pupation May 21, where eggs had been placed on the 12th of April. We have shown the egg period at that time to be 15–18 days. This would leave the life of these larvae as 22–25 days up to the time of making pupal cells in the soil. May 31, 1926 pupae were seen where eggs had been placed April 19, 1926. This would make the larval life of these specimens 22–26 days long.

Insectary records in 1927 show: (1) larvae 21 days old not pupated; (2) pupae June 16 from eggs May 3, larvae about 26 days; (3) larvae June 4, pupae June 25, larval life 21 days; (4) larvae June 4, pupae June 25, larval life 21 days; (5) eggs May 21, pupae July 2, larval life 23–27 days. From these it will be seen that *Sitona hispidula* spends 21–27 days as a larva feeding on the nodules and roots of clovers and alfalfa.

PUPA. Pupae are found scattered in the soil either close to or as much as 5–6 inches away from the base of clover and alfalfa plants on which the larvae appear to have fed. They are very delicate and, unless handled with the utmost care, will be destroyed.

PERIOD OF PUPATION. Few of our records show definitely the time spent by this insect as a pupa, but certain of our materials can be adapted to show the approximate period. Some of the insectary plants which were used to determine egg and larval periods were left for pupae,

and others, undisturbed between deposition of eggs and emergence of adults may be used. These show: (1) pupation May 31, 1926, adult seen emerged June 22, 1926, pupal period 22 days or less (the plots were not visited for a few days); (2) pupae June 16, 1927, adult July 2, 1927, pupal period more than 16 days; (3) pupae June 25, adult July 20, 1927, period less than 25 days (had not been examined for several days); (4) pupa July 2, adult July 20, 1927, pupal period 18 days; (5) egg May 21, adult July 20, 1927, pupal period 17–20 days.

Pupation occurred in the field in 1926 and 1927 during the first ten days or two weeks of June. This coincided in both seasons with the first cutting of alfalfa for hay, and preceded the cutting of red clover for hay by two or three weeks.

It is probable that the pupal period is longer in the field than in our insectary and cage tests. In 1926 pupae were observed May 31, and were present in numbers until June 17. Adults were first observed June 22, 1926. In 1927 pupation was not observed in the field until June 10, at which time the pupae were present in the ratio of 6 to 1 of pupae to larvae. The larvae were practically all in cells ready to pupate. First adults were observed in the field July 5, 1927.

In general the pupation period is seen to be between 17 and 22 days in central Illinois during June.

HIBERNATION. As previously shown, the Clover Root Curculio hibernates in the adult and egg stages. The adults are hidden in the leaves and trash in the clover and alfalfa fields. They have not been found in our many hibernation studies at the bases of hedges and fence rows, though these have been, in many cases, adjacent to clover fields in which the Curculio could be easily found.

PARASITES. Up to the present no larval or pupal parasites have been observed by us. One predatory insect, *Stenus* sp. (Staphylinidae) was taken feeding on the eggs of the Curculio at Riggston, Scott county, Illinois, April 12, 1926.

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MR. A. A. GRANOVSKY: I have been interested in the fact that insect injury leads to secondary invasion of plant parasites on clover and alfalfa. In my studies of the alfalfa "yellow top," I find that the roots are severely injured by depletion of reserve material in the root

system due to leafhopper feeding. The roots are weakened, and on repeated freezing and thawing during the winter are mechanically injured, and in the spring invariably succumb to alfalfa wilt, which is a bacterial disease. Since wounds are absolutely necessary for the entrance of bacterial wilt organism into the roots of the plant, the clover root curculio and other insects undoubtedly play an important role in the dissemination of alfalfa wilt and possibly other diseases. I would like to call Mr. Bigger's attention to this phenomenon and shall be interested in the results of his observation.

PRESIDENT T. J. HEADLEE: The next paper is by A. F. Satterthwait.

ANAPHOIDEA CALENDRAE GAHAN, A MYRMARID PARASITE OF CALENDRA

By A. F. SATTERTHWAIT, *Webster Groves, Mo.*

(Withdrawn for publication elsewhere)

PRESIDENT T. J. HEADLEE: The next paper is by G. M. List.

SOME EXPERIENCES IN BREEDING *TRICHOGRAMMA MINUTUM* RILEY

By GEORGE M. LIST, *Colorado Agricultural Experiment Station*

ABSTRACT

An account is given of 2 years experience in breeding *Trichogramma minutum* Riley, by using *Sitotroga cerealella* Ol. eggs as the host. Mites which proved a serious menace to the supply of *S. cerealella* have been controlled by sulphur. Low humidity prevents many *S. cerealella* larvae from making entrance into the grain. The ratio of reproduction of *T. minutum* Riley has varied a great deal. The presence of sulphur is a factor in this, but the condition may prevail when sulphur is not used. *S. cerealella* eggs are somewhat more readily parasitized after being stored in a refrigerator. They have been parasitized successfully after being held for 82 days at a temperature of 38 degrees Fahrenheit.

A project in the breeding of *Trichogramma minutum* Riley was started by the Colorado Experiment Station and State Entomologist cooperating, in August 1927. The object was to determine if this parasite could be made of more value in the handling of our rather extreme codling moth condition of certain sections of the state. The work has been pushed rather vigorously for over two years with only indifferent results, but since a number of other workers are interested in the same study, it is feltthat a brief account of some of our experiences may be of interest.

The technique used has been developed largely from that of Mr. Stanley E. Flanders, of California, and a number of suggestions from A. B. Baird and Geo. Wishart of Ontario. The writer was assisted in the laboratory during the winters of 1927–28 and 1928– 29 by Mr. W. P. Yetter, Jr., and during the remainder of the time by Mr. Carl Bjurman. Mr. Yetter handled the liberation of the parasites in the orchard during 1928 and Mr. Louis G. Davis during 1929.

A number of hosts have been tried out but *Sitotroga cerealella* Ol. has proven the most adaptable to large scale breeding work, and what I have to say here will refer to that species. Our original supply of *Sitotroga cerealella* Ol. was secured from a grain storage room on the College campus. Later several thousand eggs were sent us by Mr. S. E. Flanders of California.

Our supply of *T. minutum* was secured by collecting parasitized codling moth eggs in the orchards at Grand Junction during the late summer of 1927. They have been bred continuously under artificial conditions since that time. However, other material secured from the following sources was added; Stanley E. Flanders, Saticoy, California, spring of 1928; A. B. Baird, Chatham, Ontario, spring of 1929; and from the orchards at Grand Junction, Colorado, during the late summers of 1928 and 1929. It is not known how effectively the introduced material interbred with that on hand.

Some ten different grains have been tried in the *Sitotroga* breeding, but corn and wheat have proven the most practical and have been used almost exclusively. The larvae seem to prefer wheat to the corn or else they are able to make entrance into the grains more readily. The moths bred from wheat, however, are smaller than those from corn and not so desirable.

The grain has been handled in bins 48 inches long, 26 inches wide and 3 inches deep, covered with slats $\frac{1}{8}$ of an inch apart. These are stacked in piles 8 high on an incline of about 30 degrees with the stacks arranged with an aisle 24 inches wide. A large percentage of the moths work upward into this aisle where they are collected by means of suction from a vacuum sweeper. Bins of the size used are too long to handle most easily and the grain in the center has not been as heavily infested as nearer the ends. The following two types of cages for egg produciton have been found the most satisfactory.

1. This has been described and used successfully by Flanders. Ours consisted of a tin or cardboard cylinder $7\frac{1}{4}$ inches in diameter, 10 inches high with caps made of 20 mesh screen. These are placed before a fan so a gentle breeze will go upward through the cylinder. This acts as a

stimulant to oviposition and the eggs drop through the lower screen and fall beneath the cage.

2. This is a standard 6 by 8½ battery jar. Its use has been developed largely by Mr. Carl Bjurman. The moths are taken directly into it by the suction collector and retained by an inverted manilla paper cone that fits snugly in the top. The egg-laying device is based on the theory that the moth naturally pushes her eggs into crevices or places where there is a certain amount of friction on the tip of the abdomen. This condition is made by wrapping a manila paper cylinder, 3½ inches in diameter and 5 inches high in a spiral fashion with a $\frac{5}{16}$ inch tape of medium to light celluloid leaving ¼ inch between the spirals. The celluloid should be slightly curved laterally. This can be done by cutting both edges of it from the same side and by pressing the strip through its entire length with some dull round pointed instrument as a nail punch. The convex side of the tape is then wrapped against the cylinder thus leaving each edge slightly raised. This makes crevices to the liking of the females and their eggs are pushed under the tape from both sides. When the tape, which has been fastened at each end by a paper clip, is removed, practically all the eggs adhere to the cylinder. They can be handled on this paper or brushed off with a medium stiff brush.

A cylinder of the size mentioned will take a tape about 6 feet in length and almost 50 per cent of the cylinder surface will be available for egg laying. Some three or four notches should be placed in the lower end of the cylinder so the moths can crawl in and out. We have found it advantageous to drop a second cylinder that has a ¾ inch greater diameter, over the one with the tape, as the moths like to congregate out of the direct light. If desired several cylinders of different diameters, all wrapped with the tape, can be placed in one jar. However, the one cylinder will furnish egg laying surface for from 5000 to 8000 moths if a new cylinder is given each day. This cage has the advantage of preventing all useless waste of energy by the moths. They are seldom seen fluttering or even crawling about, and an increased egg production is the result.

The angoumois grain moth is a more serious pest in the more humid sections. We find our low relative humidity of the semi-arid section a great handicap in the breeding work. The greatest difficulty from this lack seems to occur with the newly hatched larvae as they are unable to make entrance into the grain. In a recent test in which 500 kernels representing five different kinds of grain were exposed to 500 newly hatched larvae in a classroom with the relative humidity in the

neighborhood of 20 per cent, not a single larva made entrance. In a duplicate test made with a relative humidity of from 35 to 50 per cent, 37 or about 7½ per cent made entrance. While in an incubator with the relative humidity in the neighborhood of 80 per cent, 338 or more than 56 per cent entered.

We are attempting to maintain a higher humidity in the main breeding laboratory by forcing a current of air through a fine spray of water in the summer time and by introducing steam into it during the colder weather. This is only partly satisfactory. In order to overcome this great loss of the newly hatched larvae while infesting a new supply of grain for spring moth production, small quantities of it are kept in an incubator where the humidity can be maintained at about 80 per cent with a temperature of 80 to 85, until all the eggs on the cards have hatched and the larvae have made entrance.

Another very serious problem in the production of the parasite host has been mites. Our first experience came in March of 1928 when our infestation was so badly reduced that the parasite breeding work had to be almost discontinued. Two species of mites were responsible, one an undetermined Gamasid and the other *Pediculoides ventricosus* (Newport). The latter became so numerous that workers in the laboratory had considerable trouble with the characteristic hive-like body eruption that they cause. Much work has been done in order to avoid or to control these mites. It was found that certain sulphurs were quite effective in destroying the mites when very young but none of the sulphurs destroyed the older individuals. Preliminary results of these tests were reported in "Scientific Notes," JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 21, No. 6, December, 1928. It has been interesting to note that only two sulphurs of a number of samples tried, were effective. One was from a sack of dusting sulphur that has been on hand for six or eight years. Its origin is unknown. The other is a by-product sulphur. Two suggestions have been offered as to why these two sulphurs were the more effective. The first is that they were of finer particles and exposed a greater surface area, but the manufacturers of the other samples will not admit this. The second suggestion is that the old sample which was the more effective and the by-product sulphur were more acid, but tests showed two ineffective samples to be the most acid. The mites are now well under control. We occasionally see one of the Gamasid mites in the laboratory but they have not increased during the last eight months and are not numerous enough to do appreciable injury. The *Pediculoides ventricosus* has not been taken in the laboratory since last March. At that time the laboratory

was thoroughly cleaned and fumigated and a supply of grain brought in with which every precaution had been taken to keep it free from mite infestation. This precaution and the presence of sulphur seem to be responsible. We are, however, planning to infest smaller quantities of grain in the future, and get these infestations as high as possible with the idea that the moth production value of the grain can be secured in about two or three generations, thus permitting a quicker turnover. This may even enable us to keep the mites under control without the use of sulphur.

A number of difficulties have been encountered in the handling of *Trichogramma minutum* Riley. Many variations in the method have been tried. The best result has been by exposing the *Sitotroga* eggs to the *Trichogramma*, under a Petri dish inverted upon plate glass, blotter paper or soft cloth with an artificial light from 20 to 30 inches above. With a temperature of 80 to 83 degrees the *Trichogramma* will develop in 8 or 9 days. The petre dish has proven too small a unit for large scale production so we have been trying, with very good success at times, a 4 by 5½ inch battery jar. These can be inverted upon a soft cloth to prevent the escape of *Trichogramma* on account of irregularities of the top, and the unit capacity much increased. These are of such a size that the egg cylinders described above can be used without the eggs being transferred to the small cards as used in the petri dishes. By using egg cylinders of slightly different diameters, several can be placed in one cage and a hundred thousand or more eggs exposed at one time.

Our greatest difficulty has been a very irregular rate of reproduction. This has not varied so much with different cages of the same date, but has gone in more or less definite cycles of considerable length. At times we have had difficulty in maintaining a reasonable amount of breeding stock while at others the rate of increase has been all that could be desired and our supply of host eggs was the limiting factor. Our first real serious decline of this nature came in July, 1928, shortly after the laboratory had been dusted with sulphur. The natural conclusion was that the sulphur in some unknown way was responsible. We are still convinced that it has been a factor but possibly not the only one. Since the fall of 1927 we have had six periods when poor reproduction was secured. Two of these occurred when sulphur was not being used, and we should state good results have been secured with eggs from moths reared in sulphured corn. During last August, September and October, our rate of reproduction was easily 4 to 1 and some times higher. This began to decline during November and at the

time of writing we are having difficulty in getting a ratio of reproduction of 1 to 1. The same methods and equipment are being used, and the eggs are produced from moths coming from the same bins in which the grain was dusted with sulphur at the time they were filled. In addition to this a small supply of eggs has been available from a source free of sulphur. The parasitism has been only slightly better than with the eggs coming from sulphured grain.

It has been interesting to note that eggs placed in cold storage for a few days are better parasitized when exposed than fresh ones. From 4 to 15 days at a temperature of 38 to 40 degrees Fahrenheit show the best results. The parasitism, however, continues good much longer. A good parasitism of 62 day old eggs and a limited parasitism of 82 day old eggs has been secured.

The *Trichogramma* that were reared from the eggs that were parasitized after 62 days were about 12 hours longer in developing than others reared from fresh eggs. In this particular case the adults seemed quite normal and gave a good ratio of increase when given eggs. The eggs should be stored where the moisture is high enough to prevent rapid desiccation. An electric refrigerator is too drying unless a special moisture chamber is provided. This method of storing the *Sitotroga* eggs offers great possibilities in meeting demands for large numbers of *Trichogramma* for a definite time.

The idea was suggested that possibly under our conditions there was a toughening of the chorion to a point where parasitism was impossible. Working along this line Mr. Leslie B. Daniels, developed a method of determining quite accurately the gram weight necessary to puncture eggs with a point of given size. A paper given on this work by Mr. Daniels at the 1929 Rocky Mountain Conference of Entomologists shows that there is a considerable variation. For example Canadian eggs received through the cöoperation of A. B. Baird, Chatham, Ontario, showed an average penetration of .416 gram while with the Fort Collins eggs of approximately the same age, it was .785 gram, or it took 1.8 times more pressure to puncture the Fort Collins eggs. In another case eggs received from moths reared at Fort Collins, but from Canadian material showed an average penetration when 24 hours old of .658 gram in comparison to 1.028 grams for eggs from Fort Collins material. There is an increase in the gram weight necessary to penetrate eggs as they get older when kept in our moth rearing laboratory, as the following averages will indicate: 24 hours, 1.02 grams, 48 hours, 1.01 grams, 72 hours, 1.04 grams, 96 hours 1.18 grams, 120 hours, 1.27 grams and 144 hours, 1.34 grams.

The placing of eggs on a moist blotter slightly softens the chorion. Refrigeration does likewise, the moist chamber having a greater effect than a dry one. The average gram weight necessary to penetrate eggs 48 hours old directly from the moth rearing laboratory was .51 gram. After 24 hours under moist refrigeration it was .436 gram and under dry .4 gram. After 48 hours under the same conditions it was for the moist chamber eggs .286 gram and for the dry .414 gram.

Knowing that the *Trochogramma* breeds in such a large range of host eggs it hardly seems likely that its ability to puncture eggs of a single species would be so limited, however, the study is of sufficient interest to carry farther.

The storing of *Trichogramma* under refrigeration has not been very effective. From our observations best results are secured when they are placed in the refrigerator on the 5th or 6th day of an 8 day development period. The humidity should be quite high and the temperature from 35 to 40 degrees Fahrenheit. While some adults have emerged after 60 days storage there is a marked weakening after 20 days.

Our orchard liberations have not been in numbers enough to show positive results. In 1928 the liberations were all quite early in the season when first brood codling moth eggs were present. The weather conditions at the time were rather adverse. The parasitism in the orchard was no higher than in other orchards of the general section. Liberations on the second brood eggs in 1929 seemed to show some results but the liberations could not be extended over a sufficiently long period to make a reliable test. Codling moth eggs on apple leaves, placed loosely in a battery jar, have always been well parasitized when exposed to *Trichogramma*.

MR. J. L. HORSFALL: It might be of interest right here to relate an experience which Dr. Moore and myself experienced in breeding moth larvae in connection with moth proofing tests. We ran into the difficulty of mite infestation which reduced our stock of moth larvae almost to extinction. We used rabbit fur as a medium for breeding the larvae. We finally hit upon the same scheme, using the fine dusting sulphur, mixing it with rabbit fur, and the breeding has increased to a pace which is now satisfactory.

MR. W. E. HINDS: The difficulty experienced has not been that the use of sulphur decreased the deposition of eggs of the moth, but the parasite declined to attack the eggs of the moth where the sulphur had been used.

PRESIDENT T. J. HEADLEE: That was our experience with Trichogramma on the Oriental peach moth this summer.

We will now take up a paper by J. H. Hawkins.

WIREWORM CONTROL IN MAINE

By J. H. HAWKINS, *Agricultural Experiment Station, Orono, Maine*

ABSTRACT

The wheat wireworm, *Agriotes mancus* Say, is a serious pest to Maine crops. An upland species of the genus *Melanotus* is second in importance. Certain cultural practices and immune crops have been found to be effective in checking wireworm infestations. Meadows and oat fields seem to be favorite breeding grounds for the wheat wireworm. Clover, buckwheat, and peas are resistant to the attacks of these insects and potatoes are very susceptible. Fertilizer is useful in strengthening plants to withstand wireworm attacks. Drainage is helpful in controlling the wheat wireworm and fall plowing is but partially effective.

The wheat wireworm, *Agriotes mancus* Say, is the most widely distributed and destructive wireworm infesting the field and vegetable crops of Maine. Another wireworm belonging to the genus *Melanotus* has appeared during the last year in great numbers, completely destroying large areas of sweet corn on one farm. This species, although distributed over a large section, has not before been recorded as being so destructive as *A. mancus*.

Potatoes are damaged yearly by wireworms mainly in two ways. Soon after planting the seed pieces are often burrowed and a poor stand results, or there may be little injury apparent until the potatoes are nearly ready to dig. The wireworms may then bore holes in the tubers, sometimes causing small pits or they may tunnel deep into the inside, spoiling the market value of the crop in either case. Injury may be done to the seed soon after planting. Feeding wireworms may also stunt the plant, prevent it from reaching maturity, weaken the root system so that it topples over during strong winds, or the plant may be killed outright. Nearly all garden and field crops are attacked by wireworms. Resistant plants will be noted later.

Control of wireworms by soil fumigation, stomach poisoning, or by repellent action of chemicals has not yet proven entirely satisfactory under existing climatic and soil conditions of Maine. Baiting as a means of controlling the adults of *A. mancus* is a method to be encouraged. Chopped clover placed under boards and stones is effective. Poisons used in connection with these baits have not yet proved to be effective. Baiting as a control measure for the larvae of *A. mancus* has been found effective. Sprouting wheat has been found the most efficient of the baits tried, attracting an average of 25 wireworms per bait. Honey or molasses added to graham flour dough increased the value of graham flour baits and made them second to wheat in attractiveness. Sprouting corn was also effective in attracting wireworms. How-

ever, baiting involves much hand labor and unless these insects may be killed by poisons eaten with the baits, such a control method is not likely to become general.

Preliminary experiments and observations indicate that certain cultural practices are at least partially effective in control of these pests. Meadow land plowed up in May, 1928, after the grass had considerable start, was used for experimental plots in cultural methods of wireworm control. Larvae of *A. mancus* were found scattered throughout the soil at the time of plowing and later, but apparently the stand of grass in the meadow had not been affected by their feeding. This was due, no doubt, to the large amount of vegetation present. Silage corn, sweet corn, potatoes and oats were then planted. Slight injury was noted to corn and oats, but potatoes alone were seriously injured. Early in the season some of the seed pieces were so badly burrowed that an uneven stand resulted. Later wireworms fed upon the growing tubers in such numbers that mature potatoes were practically worthless. Except for a strip of meadow and plots where oats were grown, the entire field was plowed during the fall of 1928. Sweet corn, silage corn, oats, potatoes and buckwheat were planted for 1929 crops. Again early season injury by wireworms was light. Although wireworms were plentiful in the soil, there was not sufficient concentration to cause a large amount of injury. Later in the season injury was apparent when potatoes were nearing maturity. Plots for 1929 were planted crosswise of 1928 plots and the 1929 infestation varied with previous crops and treatment. The heaviest infestation (at the rate of 21,000 per acre) was in potatoes in soil which had been planted to oats during 1928. A plot nearby which had been kept fallow during 1928 was found to have the wireworm population reduced at the rate of 13,000 per acre.

Wireworms at the rate of 7,200 per acre were found in lighter soil where potatoes were grown following a 1928 crop of potatoes. Previous to 1929 this soil was not so heavily infested as plots already mentioned. There were some wireworms present in soil of corn plots, but they were more widely scattered than they were in the potato plots. Soil planted to buckwheat produced a few wireworms, but those present were deep in the soil and apparently many of them had migrated to nearby plots whenever possible. It is significant that no young wireworms from this year's crop of eggs were taken in the cultivated plots. This circumstance corroborates other data on the ovipositing habits of the wheat wireworm in Maine. Apparently very few eggs are laid in fields kept in cultivated crops. This, coupled with the fact

that wireworm infestation often follows cultivated crops planted in soil plowed from meadow lands, is an argument against including hay crops such as timothy or other similar grasses which may stand for several years, in the rotation. Clover has been found to thrive even when wireworms are present in large numbers and is desirable if a hay crop must be raised. Peas planted in infested soil are also resistant to wireworms and may be included in such a rotation. If a pea crop is planted in rows and cultivated, it is an especially good one to be grown in wireworm infested soil for peas are resistant to wireworm attacks and cultivation discourages congregation of the adults for breeding. Oats are not severely injured except during years of exceptional wireworm abundance, but data seem to indicate that the adults deposit eggs in oat fields. Corn may be severely injured, although it can sometimes be safely grown in the rotation the second year following sod. Available data on the subject indicate that the limit of tolerance of sweet corn to wireworm injury is considerably greater than that of potatoes. In case of heavy wireworm infestation both corn and potatoes are to be avoided. Either peas, or clover, or buckwheat is a desirable crop for the first two years after the field has been plowed from meadow, if the wireworm population is large. Wireworms are capable of some migration and a small field or garden may continually be infested by wireworms from nearby sod land. This has been demonstrated by counts of areas bordering meadow land before placing of cyanide barriers, after they had become ineffective, and by observations of small areas surrounded by meadows. Wireworms were also induced to move down a glass tube toward a corn plant by drawing a draft of air from the plant to the wireworms, indicating that they are able to locate food by perception of odor.

The wheat wireworm inhabits low lying places and drainage has been recommended as a control measure for this species. Data collected are insufficient at present for definite conclusions, but in at least one case drainage has reduced the number of wireworms present. An undrained area, of the same soil type and which received the same general treatment in regard to farm operations on the drained area, was used as a check.

Fertilization as a method of producing crop resistance is applicable in wireworm control. At least data were obtained in one field infested by the upland wireworm, *Melanotus* sp., which bear this out. Fertilizer used judiciously stimulated growth of sweet corn and a heavy yield resulted, even though the wireworm population ran into several thousands per acre.

Fall plowing is of some value, but is not wholly effective as a means of controlling the wheat wireworm. Theoretically the pupal stage is the most vulnerable spot in the life history of this pest. In order to attack it in this stage, however, plowing would have to be done during August. Since crops are growing at this time, such a practice is not feasible. Then too, pupae of this species can stand rough handling without much damage as was demonstrated when they were dug from the ground and placed in containers in a greenhouse. Here, without special care they continued to develop to the adult stage, the rate of mortality being very low. At the time most fall plowing is done, pupae have changed to adults within the pupal cells where they spend the winter. Plowing disturbs the adults by breaking them from these cells and exposing them to the weather. If plowing is done late in the season when the weather is cold enough, the beetles evidently are not able to again enter the soil and may perish. It is interesting in this connection that bettles died in the insectary during the winter of 1927 where except for moisture, approximately outdoor conditions prevailed. Fall plowing has been observed for effect upon the larvae of both *A. mancus* and *Melanotus* sp. No direct mechanical injury by the plowing operation has been found. Those larvae exposed again entered the ground, unless as sometimes happens, they were eaten by birds following the plow.

MR. P. T. ULMAN: I should like to ask Mr. Hawkins if he has observed the larvae on gladioli. My attention was called last summer to rather severe infestation of gladioli, especially to the new corms.

MR. J. H. HAWKINS: I think I have one or two records of injury to gladioli.

MR. P. T. ULMAN: The wireworms seem to burrow in the old corms rather than the new.

MR. J. H. HAWKINS: I have one or two records of injury to gladioli but do not remember having observed such injury personally.

PRESIDENT T. J. HEADLEE: The next paper is by Walter Carter.

ECONOMIC APPLICATION OF INSECT-ASSOCIATION STUDIES

By WALTER CARTER, *U. S. Bureau of Entomology*

ABSTRACT

Studies of insect associations supplement standard methods in economic entomology. They provide data on biology of species, host-plant relationships, relations between climate and species, cyclic phenomena, plant-disease vectors, and the control of waste lands as reservoirs for economic and potentially economic insects.

Of the three lines of attack on entomological problems, one has probably been used almost exclusively in the past. This is what might be termed the "life-history" method and considers simply the insect, as such. The development of well-equipped laboratories has extended this method to include consideration of the effects of single environmental factors or of two or three of these in combination. In accordance with the standard scientific procedure from the detailed to the general, this method will no doubt remain of fundamental importance.

Within recent years the second line of attack has been much used. This depends for its success on the concept that the insect is an integral part of an environment. The simplest development along this line has been the study of particular species in relation to climate. When the environment is taken to include the host plant, the problem becomes much more complicated, but consideration of the host plant is essential in some cases, notably those where the insect is a plant-disease transmitter, or where there are alternate hosts, or where the insect is a migrant.

The third method has rarely been considered in connection with economic problems. Studies of insect associations have usually been considered purely academic, resulting in mere lists of species from some particular locality, or host plant. Such studies belong to the prequantitative days of ecology and are anathema to the taxonomists on whom the burden of species determination falls.

Such studies can be planned and executed to yield valuable economic data. This method is essentially an extension of the one just discussed. There, the insect is considered in relation to its physical and biotic environment. In this case, the entire insect community is so considered.

This method differs from the previous one principally in concept, since the insect community can be known only through its parts, that is, the individual species comprising the community. The reactions of each species are considered, however, not as isolated phenomena but in relation to the reactions of other species with which it is associated. In such a study every single species encountered is at least potentially significant even though its numbers may be so few as to eliminate it

from statistical analysis. The terms "incidental" and "errant" species should be used only for convenience in designating those species which appear rarely or in very small numbers, and it is unwise to attach any other meaning to the terms.

Data on the insect community can often be obtained at little extra cost in the course of investigations on economic insects.

Routine work on the sugar-beet leafhopper, *Eutettix tenellus* (Baker), requires that sweepings be made at regular intervals at six or seven stations on from two to four host plants; in addition, regular circuits are made between these stations. All the insects taken in these sweepings are sorted and counted.

It is recognized that such a method, or any one quantitative method, as far as that is concerned, is not adequate for getting a complete picture of all the species inhabiting an area. As a matter of fact, much interesting material is lost unless such methods are supplemented by general "collecting."

The regular sweepings do, however, give comparable sets of data, the value of which increases rapidly as successive years' data are accumulated. The applications for these data can be briefly considered:

Additions to our knowledge of the biology of species, many of which are known at present only as museum specimens. Aestivation shows clearly in the data from collections as does double broodedness. Host-plant preferences and movements from one host to another, extremely important considerations in connection with insect-borne plant diseases, are clearly shown by the data if care is taken to choose stations where pure stands of the host plants are growing. A wealth of material is available for the study of parasitism and of competition between species.

In studies on climate and insects, the insect-association study offers a rare opportunity for extending our knowledge. An area will show in the association a relatively small number of species present in large numbers and a large number of species present either rarely or in small numbers. It is assumed that the common species in any locality are common principally because of favorable climatic factors and the presence of suitable hosts. By the same token, the so-called incidental species are inferior numerically because of climatic factors under which the species can barely exist or because of limited or unfavorable food. Even the common species fluctuate in numbers and these fluctuations can be associated with different types of weather. A cool late spring, for instance, in the Twin Falls area will reduce the numbers of *Eutettix tenellus* and increase populations of cutworms and the seed-corn maggot, *Hylemyia cilicrura* Rond. Some species which normally appear only

in the outer ring of incidental species take rank as common species during years of abnormal weather. This abnormality may be in precipitation or in temperature, for instance, or merely in the incidence of these factors.

With data available for a series of years, the effects of climate and weather on the species concerned will be determined, not only in general terms but also with respect to individual factors. It might not be amiss to make a suggestion here concerning the relations such studies should bear to laboratory experiments.

Any student of autecology who has attempted to apply to a field problem the results of laboratory experiments on the effects of single climatic factors is aware of the difficulties encountered in relating the two. If the laboratory experiments, however, are based on field data they not only are more easily related but serve as a check on interpretations placed on the data from the field. From field to laboratory is a much more economical procedure than from laboratory to field.

Cyclic phenomena appear clearly in the association data. These may be of two kinds, one as a result of a combination of weather types, another more or less independent of weather and inherent in the species. It is only through study of the data of a series of years that information regarding cyclic phenomena can be obtained. Once obtained, however, the prediction of insect outbreaks can gradually be extended to include many pests of periodic importance.

Diseases of plants transmitted by insects appear prominently in association with large populations of the latter, consequently the field of investigation where specific vectors are being sought can be narrowed down materially.

There is another economic application of such data which may be of far-reaching consequence. In proximity to some of the western irrigation districts of Oregon and southern Idaho are large tracts of abandoned land. These tracts at present are largely responsible for sugar-beet leafhopper outbreaks in this section and are a tremendous reservoir for insects of all kinds. The remedy for this condition lies primarily in restoring these tracts to their original status as sagebrush-grass lands. The method of approach that is being used in investigations by the Bureau of Entomology having this object in view is through a combination of studies of plant and of insect ecology, undertaken in collaboration with the Bureau of Plant Industry. The Bureau of Plant Industry's work on the plant ecology was initiated in the spring of 1928 when Mr. R. L. Piemeisel set up a series of studies on plant succession in the Twin Falls area.

The host plants on these lands could be attacked by introducing insect species not represented at present in the association.

Species of plants could be introduced which would replace the host plants. In either case a detailed knowledge of the insect community is essential. Reference has already been made to the so-called incidental species whose numerical inferiority may be due either to unfavorable climate or to lack of suitable hosts. It can readily be seen that the introduction of a new host plant might change the status of an insect species in the latter class with unfortunate results for the introduction. A practical example of this was experienced last season. A new plant, a willow herb, appeared at one of the stations. A chrysomelid beetle which previously had been an insignificant member of the association attacked the newcomer, with the result that there was a large although temporary increase of the insect and the new host plant was practically eliminated. It is obvious, then, that plant introductions must be made only in the light of detailed knowledge of the insect association, and this is true in even greater measure if introduction of insect enemies of the host plants is to be successful.

If associational studies are conducted in connection with economic projects the only additional cost is for the routine labor necessary to handle the sorting and counting of the insects. But such studies are well worth undertaking as separate and independent projects, since it is certain that results of wide economic application will follow.

PRESIDENT T. J. HEADLEE: We will now hear a paper by F. C. Bishopp, E. W. Laake and R. W. Wells.

EXPERIMENTS WITH INSECTICIDES AGAINST CATTLE GRUBS (HYPODERMA SP.)

By F. C. BISHOPP, and E. W. LAAKE, *U. S. Bureau of Entomology, Washington, D. C.*

(Withdrawn for publication elsewhere)

MR. C. L. METCALF: I should like to ask the method of application. Do you rub it into the grub holes in the animal?

MR. F. C. BISHOPP: The method of application consists of applying the dust with a shaker can and working it in with the fingers. We feel that the thoroughness of the applications is of much importance.

MR. F. E. WHITEHEAD: Are these other materials so much better than sodium fluoride?

MR. F. C. BISHOPP: Our experience with sodium fluoride has indicated that it is not a satisfactory material for cattle grub control; not as satisfactory as the other insecticides which I mentioned.

ADJOURNMENT: 12:10 P.M.

Wednesday Afternoon Session, January 1, 1930

The session convened at 1:30 p.m., President T. J. Headlee presiding.

PRESIDENT T. J. HEADLEE: The first paper is by F. L. Campbell.

A COMPARISON OF FOUR METHODS FOR ESTIMATING THE RELATIVE TOXICITY OF STOMACH POISON INSECTICIDES

By F. L. CAMPBELL, *U. S. Bureau of Entomology*

ABSTRACT

The relative effect of acid lead arsenate and sodium fluosilicate on the silkworm was studied by three laboratory methods, namely, the sandwich method for the estimation of the median lethal dose, the sandwich method for the determination of the relation between dosage and speed of toxic action, and the simple cage test. The relative effect of the same compounds on mosquito larvae, *Culex pipiens* L., was studied by the method of Marcovitch.

It was concluded that only the first two of the foregoing methods measure the relative toxicity of stomach-poison insecticides and that the first of the two is the more practicable for the purpose. The last two methods may be suitable for measuring the relative effectiveness of stomach poisons. The cage test with appropriate insects should usually be the better of the two for this purpose.

The toxicity of sodium fluosilicate to the fourth-instar silkworm ranges from one to two times that of acid lead arsenate, depending on the method and criterion employed for its estimation. Any dose of the fluosilicate affected the silkworm more rapidly than the same dose of the arsenate.

In order to establish the toxicology of stomach-poison insecticides on a firm foundation, the toxicity of a large number of compounds should be quantitatively determined by a single good method. Since different methods give different results of varying degrees of reliability and general significance, it is desirable to make a comparative study of several methods in order to select the one best adapted for a general survey of relative toxicity. For this purpose the effects of acid lead arsenate and of sodium fluosilicate were compared by four laboratory methods.

INSECTICIDES AND INSECTS

The sample of acid lead arsenate ($PbHAsO_4$) used by the writer was carefully prepared and analyzed by C. M. Smith of the Insecticide Division, Bureau of Chemistry and Soils. It contained 33.01 per cent

As_2O_5 and 64.15 per cent PbO with about 0.04 per cent N_2O_5, 0.02 per cent moisture, and 0.08 per cent water-soluble As_2O_5. Mr. Smith also contributed a sample of sodium fluosilicate containing 99.5 per cent Na_2SiF_6. Both compounds were therefore very nearly pure.

Silkworms of the fourth instar weighing between 0.3 and 0.4 gram were used as test insects in the first three of the four methods to be discussed. Larvae of a mosquito, *Culex pipiens* L., in the last instar were used in the method of Marcovitch (*3, p. 33*). They were reared in jars to which dried blood had been added as recommended by Marcovitch (*3, p. 26*).

The Sandwich Method for the Estimation of the Median Lethal Dose

The sandwich method has been described in detail by Campbell and Filmer (*2*). It is sufficient to mention here the few refinements that have been made in the method since it was published. In the dusting apparatus a bell jar was substituted for a battery jar and the wooden top of the dusting stand was replaced by a piece of plate glass with a hole bored through the center to admit the blast of dust into the bell jar. The dust that falls on this plate can be swept up and used again if the quantity of the sample to be tested is so small that conservation is necessary. Instead of placing the cover glasses directly on the glass plate bearing the leaf disks, they were placed on pieces of black paper glued to the plate. The paper prevented the cover glasses from sliding on the plate, and raising them slightly above the surface of the plate made them easier to pick up with forceps.

Table 1 shows that all larvae that took doses less than 0.07 mg. per gram of body weight recovered and all that took doses more than 0.10 mg. per gram died. The numbers of larvae in these sublethal and lethal zones have no significance except to show the numbers that were wasted in order to delimit the significant intermediate zone in which some larvae died and others recovered. The numbers of larvae in the intermediate zone, however, are important for the determination of the median lethal dose,[1] the dose that kills 50 per cent of the insects. The intermediate zone of Table 1 shows that the dose of both compounds that

[1]Trevan (*5, p. 190*) proposed the expression, median lethal dose, and defined it as "the dose which kills 50 per cent of a large group of animals." It is more significant than the older expression, minimal lethal dose, a single definition for which has never been generally accepted. Moreover, the median lethal dose is not so variable as the least dose required to kill all or nearly all the individuals of a group and may therefore be determined accurately with fewer individuals.

kills 50 per cent of the insects lies between 0.07 and 0.10 mg. per gram. The writer realizes that the number of insects in the intermediate zone are too few, especially in the case of sodium fluosilicate, to permit more than a guess as to the value of the median lethal doses. It is certain, however, that these doses are nearly the same for both compounds and are not far from 0.09 mg. per gram. By this method the two compounds are therefore roughly equal in toxicity.

TABLE 1. THE EFFECT, IN TERMS OF DEATH OR RECOVERY, OF DOSES OF ACID LEAD ARSENATE AND OF SODIUM FLUOSILICATE ON SILKWORMS OF THE FOURTH INSTAR

Zone	Dose	Acid Lead Arsenate		Sodium Fluosilicate	
		Died	Recovered	Died	Recovered
	Mg./gm.	*Number*	*Number*	*Number*	*Number*
Sublethal.....	0.02	—	2	—	3
	0.03	—	2	—	3
	0.04	—	7	—	3
	0.05	—	3	—	8
	0.06	—	10	—	2
Intermediate..	0.07	1	7	1	2
	0.08	2	7	1	3
	0.09	4	6	1	1
	0.10	5	3	4	1
Lethal.....	0.11	10	—	1	—
	0.12	13	—	4	—
	0.13	10	—	3	—
	0.14	12	—	1	—
	0.15	7	—	7	—
	0.16	7	—	5	—
	0.17	10	—	3	—
	0.18	5	—	3	—
	0.19	4	—	1	—
	0.20	8	—	2	—

The best way to determine median lethal doses was suggested by Trevan (*5*). A curve showing the relation between dosage and percentage of mortality is plotted and the dose required to kill 50 per cent of the animals is read off from the curve. According to Trevan it is desirable that each point on the curve should represent the percentage or mortality of at least 30 animals. Because doses can not be exactly predetermined in the present method, it would require hundreds of insects and much time to cause at least 30 insects to take each of the doses in the intermediate zone. In the initial stage of the development of the toxicology of stomach-poison insecticides it is questionable whether it is necessary to determine median lethal doses with a high degree of accuracy. Later the constants of toxicity may be redetermined more accurately by some better method just as physical and chemical constants have been continually improved.

If it is assumed that the average susceptibility of the silkworm to acid lead arsenate did not change during the two summers it was used as a standard, the combined results of the writer on this compound can be used to plot a dosage-mortality curve (Fig. 37) nearly meeting Trevan's

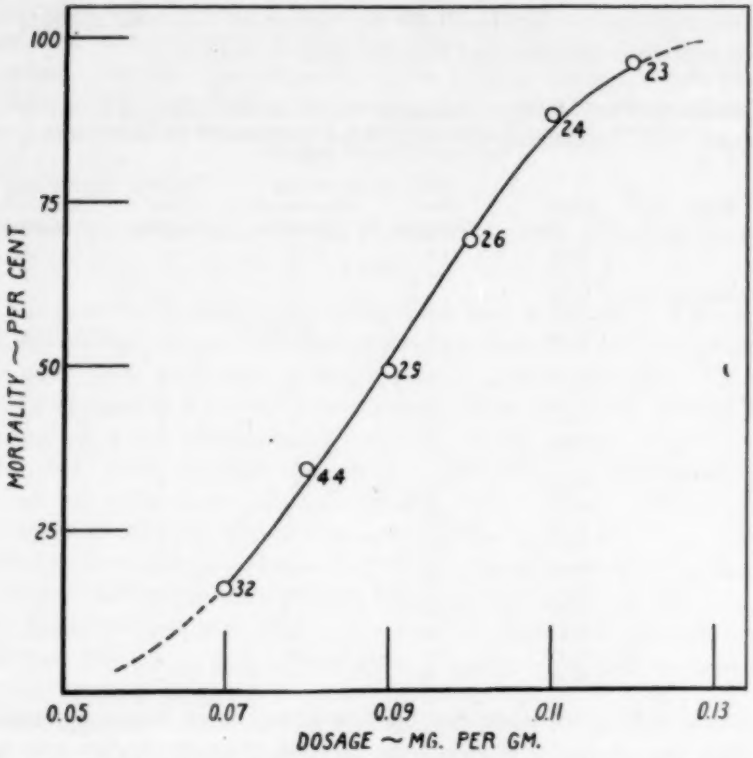

FIG. 37.—The relation of the percentage of mortality of fourth-instar silkworms to the dose of acid lead arsenate.

requirements. The figure beside each point represents the number of larvae used to determine that point. The dose of acid lead arsenate that should kill 50 per cent of a large number of fourth-instar silkworms is 0.090 mg. per gram, confirming the earlier estimate of Campbell and Filmer (*2*) from more limited data.

THE SANDWICH METHOD FOR THE DETERMINATION OF THE RELATION BETWEEN DOSAGE AND SPEED OF TOXIC ACTION

In the determination of median lethal doses, the time elapsing between the taking of the dose and the death or complete recovery of

individual insects is not taken into consideration. One is interested only in ultimate death or recovery. The median lethal dose therefore does not tell the whole story of toxicity. Perhaps the most nearly complete picture of the acute toxicity of a compound would be obtained by plotting the reciprocal of the recovery period and of the survival period against doses covering as wide a range as possible. One would get a graph resembling the cross section of a valley, one side representing the effect of sublethal doses, the other side representing the effect of lethal doses, and the bottom of the valley representing the region of the median lethal dose. The sandwich method will provide data for such a graph if the recovery period or the survival period of each poisoned insect is determined. For the present comparison of the toxicity of acid lead arsenate and sodium fluosilicate the effects of lethal doses only were studied.

Since it was necessary to have as many as 80 poisoned larvae under constant observation, the larvae had to be exposed to room temperatures from the time they took their doses until they died. In order to obviate the effect of variable temperatures as far as possible, the two compounds were compared in parallel and the work was done only on hot days when the temperature ranged from 28° to 32° C.

Preliminary experiments[2] in 1928 indicated that more than one end-point would be useful for comparing the effect of the two compounds. In the experiments of 1929, herein recorded, two end-points were determined for each poisoned larva: the "knock-out" point, i.e., the time at which a larva failed to regain its feet after being pushed over, and the death point, i.e., the time at which the last feeble response to touch failed. The time that elapsed from the taking of the dose to the knock-out point and to the death point are here called the active period and the survival period, respectively. The reciprocal of the active period is plotted against dosage in Figure 38, and the reciprocal of the survival period is plotted against dosage in Figure 39. Each circle in both figures represents an observation on an individual insect. When two or more circles happened to coincide, they were scattered enough to make each one visible in order to show the total number of observations. Such changes of position were well within the experimental error. The end-points may have been in error from as much as 5 minutes in the shortest periods to as much as 60 minutes in the longest periods.

[2]In these experiments the writer was assisted by Mr. R. S. Filmer; in later experiments, by Miss Abby Holdridge.

Figure 38 shows that the speed of toxic action of sodium fluosilicate, in terms of the reciprocal of the active period, becomes greater than that of acid lead arsenate as the dosage increases. Figure 39 shows that the speed of toxic action of the fluosilicate, in terms of the reciprocal of the survival period, is less than that of the arsenate at the lower doses and becomes equal to and greater than that of the arsenate as the dosage increases. Together, the two figures show that the silk-

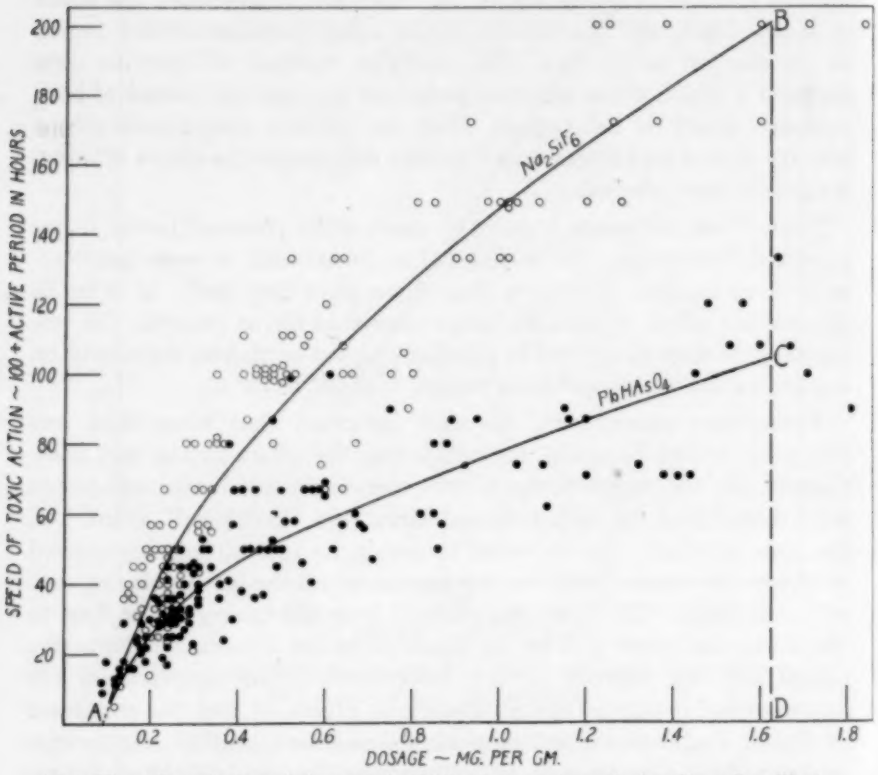

FIG. 38.—The relation of dosage of acid lead arsenate and of sodium fluosilicate to the reciprocal of the active period in the silkworm of the fourth instar.

worm is incapacitated more quickly by the fluosilicate, but that death usually results first from the arsenate at lower doses. This difference follows from the fact that all parts of the body of the silkworm poisoned with the arsenate die at about the same rate, whereas the posterior end of the body of the silkworm poisoned with the fluosilicate may show signs of life much longer than the rest of the body. An explanation was suggested by observations on the effect of these two compounds on the

heart beat of the silkworm. The arsenate has so little effect on the heart that it is usually still beating feebly when the insect is called dead; the fluosilicate stops the beating of the heart long before the insect is incapacitated. The distribution of the arsenate throughout the body of the insect should therefore be more uniform than that of the fluosilicate and should result in a more uniform death rate of the different parts of the body.

How can relative toxicity be measured from Figures 38 and 39? If the ratio of the speeds of toxic action of the two compounds at any

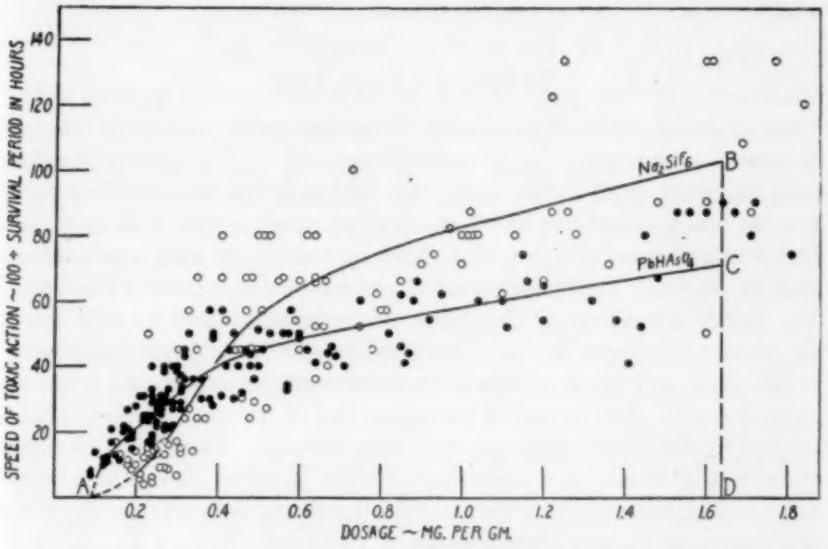

FIG. 39.—The relation of dosage of acid lead arsenate and of sodium fluosilicate to the reciprocal of the survival period in the silkworm of the fourth instar.

particular dose is taken as a measure of relative toxicity, it will be found that acid lead arsenate is more toxic than sodium fluosilicate or vice versa, depending on the choice of end-point or of dose. It is preferable to get a ratio representing relative toxicity over the whole dosage range. As pointed out by Campbell (*1, p. 732*), this can be done by summing up the speeds of toxic action over the whole dosage range and by taking a ratio of the sums. The summation was accomplished by measuring the areas ABD and ACD (Figs. 38 and 39) by a planimeter. The ratios of these areas indicate that the fluosilicate is about 1.8 times

as toxic as the arsenate in Figure 38, and about 1.3 times as toxic as the arsenate in Figure 39.

Although the shape and position of the curve for the fluosilicate in Figure 39 are very uncertain, there can be no doubt that the knock-out point actually leads to a larger ratio than the death point. In other words, relative toxicity here depends on the choice of end-point. Since larvae that reach the knock-out point either from the arsenate or from the fluosilicate are sure to die, and since at that point they may be considered dead in an economic sense because they can no longer eat, the knock-out point is just as practical as the death point and is preferable to it because the knock-out point can be determined more accurately and in less time than the death point.

The Simple Cage Test

Some entomologists believe that if two stomach-poisons are sprayed or dusted as equally as possible on plants and if insects are allowed to feed freely on them, it is possible to determine the relative toxicity of the two compounds. In the present application of the cage test mulberry leaves were sprayed with acid lead arsenate and with sodium fluosilicate, both at 2 pounds to 50 gallons of water. After the leaves had dried, silkworms of the fourth instar were allowed to feed freely on them. Mulberry leaves were also dusted heavily with the same compounds and fourth-instar silkworms were allowed to eat as much as they could. The effects of the spray and of the dust were compared in parallel and the comparison was repeated once. The period in which there was a 50 per cent mortality of each group of larvae was determined. For example, in a group of 40 larvae the survival period of the 20th worm to die was recorded.

The results are shown in Table 2. Although the quantity of the arsenate per unit area of leaf surface was much greater as a dust than as a spray, the period in which 50 per cent mortality occurred was about the same for the dust and for the spray. Perhaps the average quantity of the arsenate consumed was almost independent of the concentration of the poison on the leaf surface. The quantity of the fluosilicate per unit area of leaf surface was also greater as a dust than as a spray, but in this case the different average periods of 50 per cent mortality showed that the insects consumed more of the dust than of the spray, or, in other words, that the quantity of the fluosilicate that is consumed is a function of its concentration on the leaf surface. As a result, the toxicity of the fluosilicate appears to be about half that of the arsenate at a low

concentration on the foliage and about twice that of the arsenate at a high concentration on the foliage.

TABLE 2. THE EFFECT OF THE FOURTH-INSTAR SILKWORM OF ACID LEAD ARSENATE AND SODIUM FLUOSILICATE SPRAYED AND DUSTED ON MULBERRY LEAVES

Application	Number of Larvae	Period of 50 Per cent Mortality: Acid Lead Arsenate	Sodium Fluosilicate	Relative Effect: Speed of Toxic Action of Na_2SiF_6 ÷ That of $PbHAsO_4$
		Min.	*Min.*	
Spray	40	165	300	0.5
	30	185	345	0.5
Dust	22	165	90	1.8
	36	215	100	2.2

THE METHOD OF MARCOVITCH

Ten mature larvae of *Culex pipiens* L.[3] were placed in 50 c.c. of water in each of eight 100-cc. beakers. The beakers were set in a water bath at 27.6±0.1° C. Four quantities of acid lead arsenate and of sodium fluosilicate, 0.025, 0.050, 0.075, and 0.100 gram, were weighed out on glass slides and were added rapidly to the beakers and stirred. Each of the four quantities of the fluosilicate was completely soluble in 50 cc. of water. The time was recorded at which the fifth larva in each beaker failed to respond by wriggling to gentle prodding with the stirring rod. This set of experiments was repeated six times in the course of a week. The results are shown in Table 3.

TABLE 3. THE EFFECT OF ACID LEAD ARSENATE AND SODIUM FLUOSILICATE ON MATURE LARVAE OF *Culex pipiens* L. BY THE METHOD OF MARCOVITCH

Quantity of Poison in 50 c.c. of Water	Acid Lead Arsenate: Mean Period 50 Per cent Mortality	Standard Deviation	Sodium Fluosilicate: Mean Period 50 Per cent Mortality	Standard Deviation	Relative Effect: Speed of Toxic Action of Na_2SiF_6 ÷ That of $PbHAsO_4$
Gm.	*Min.*	*Min.*	*Min.*	*Min.*	
0.025	124	18	196	31	0.6
0.050	139	30	123	11	1.1
0.075	124	16	99	18	1.3
0.100	137	22	77	5	1.8

The mean period of 50 per cent mortality is independent of the quantity of the arsenate used but is dependent on the quantity of the fluosilicate. This is brought out more clearly in Figure 40, which shows that the speed of toxic action of the arsenate is constant over the range

[3]The writer is indebted to Mr. C. T. Greene of the U. S. Bureau of Entomology for identifying the species.

of quantities used, whereas the speed of toxic action of the fluosilicate is directly proportional to the concentration over the same range. It is easy to understand this difference. The arsenate, being practically

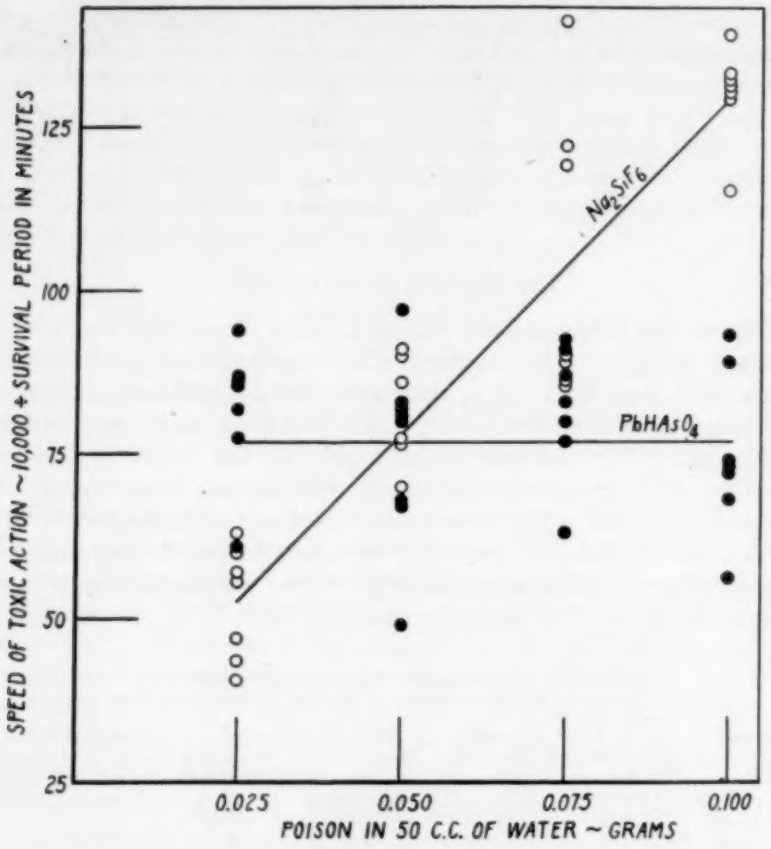

FIG. 40.—The relation of the quantities of acid lead arsenate and of sodium fluosilicate, to which mosquito larvae were exposed, to their speed of toxic action in mature larvae of *Culex pipiens* L.

insoluble, settled to the bottom of the beakers where even the least of the four quantities used was much larger than the maximum quantity that the larvae could consume. Since the arsenate was equally accessible to the larvae in each beaker, about the same mean dose must have been taken in each beaker, resulting in the same mean period of

50 per cent mortality. The fluosilicate, being completely soluble, affected the larvae in proportion to its concentration, as all soluble poisons do when larvae are immersed in their solutions. As a result the fluosilicate appears to be from 0.6 to 1.8 times as toxic as the arsenate, depending on the quantities of the poisons compared.

Discussion

In the last three methods herein studied the relative toxicity of acid lead arsenate and sodium fluosilicate was expressed as a ratio of speeds of toxic action. This is a legitimate way of expressing relative toxicity only if the speeds of toxic action are the result of equal mean doses. For example, if the mean dose of compound A is ½ that of compound B and if the speeds of toxic action are the same, it would not be logical to say that A and B are equally toxic. Obviously A is more toxic than B, because a smaller quantity of A produces the same effect as a larger quantity of B.

In the last two methods the mean doses taken are unknown. Workers who have used these methods for determining relative toxicity may have assumed that mean doses of different compounds, although unknown, are equal. It is probable, however, that the mean doses of the arsenate and the fluosilicate in the last two methods are not equal, because in both methods the mean period of 50 per cent mortality appears to be independent of the quantity of the arsenate offered to the larvae but dependent on the quantity of the fluosilicate. In other words, the relative consumption of the compounds by the larvae seems to change as the quantities of the compounds offered to the larvae are increased. Since the mean quantities consumed are unknown, one does not know which, if any, of the quantities offered lead to the consumption of equal mean doses. The greater the difference in the toxicity of the compounds being tested, the greater should be the difference in the mean quantities consumed and the larger the error in the estimation of relative toxicity.

For reasons just given, the cage test, the method of Marcovitch, and any other method in which insects feed freely and consume unknown quantities of poisons are unsuitable for the quantitative determination of the relative toxicity of stomach-poison insecticides. Such methods, however, may be useful for preliminary estimations of the relative effectiveness of stomach poisons. The method of Marcovitch will now be examined as a measure of the relative effectiveness of stomach poisons.

As a result of a single experiment Marcovitch (*3. p. 33*) found sodium fluosilicate six times as effective as acid lead arsenate against *Culex quinquefasciatus* Say. On repeating this experiment Marcovitch and Stanley (*4, p. 6*) found the former 5.6 times as effective as the latter. In both experiments saturated or nearly saturated solutions of the fluosilicate were used. Consequently the maximum difference in effectiveness between the two compounds was obtained. The ratios found by the writer (Table 3) were much smaller, partly because saturated solutions of the fluosilicate were not used, but largely because *C. pipiens* was more susceptible to the arsenate than *C. quinquefasciatus*, or because the former ate more of that poison than the latter, or for both reasons.

The susceptibility of *C. pipiens* to the fluosilicate was found to be influenced by the environment in which the larvae developed. The results given in Table 3 were obtained with larvae taken from jars to which the dried blood was added several weeks before the period of the experiments. Larvae that were taken from jars to which the dried blood was added a few days before the period of the experiments were much more susceptible to the fluosilicate, 50 per cent of the larvae being killed by all four concentrations in from 40 to 45 minutes. Their susceptibility to the arsenate, however, was practically unchanged. Suspecting that the difference in results might have been due to the presence of more than one species of mosquito larva, the writer took samples of larvae from the jars to Mr. C. T. Greene, who found all of them to be *C. pipiens*.

Since the method of Marcovitch may yield widely different results, depending on the quantities of poisons compared and on the species of larva and its environment, and since such results do not necessarily apply to the insects against which stomach poisons are ordinarily used, it seems to the writer that the simple cage test with appropriate insects is a better method for estimating the relative effectiveness of stomach poisons than the method of Marcovitch.

It has been shown that neither the cage test nor the method of Marcovitch measures the relative toxicity of stomach poisons. The sandwich methods are also open to criticism because they give no information on the relative parts of doses that actually cause death. For example, if equal doses of compounds A and B are consumed and their effects are the same, it may be argued that their toxicities are identical only if equal fractions of the doses enter the tissues and take part in the reactions leading to death. If one-tenth of the dose of A and one-half of the same dose of B enter the tissues and produce the same

effect, A might be considered more toxic than B. If one takes this point of view, none of the methods herein studied measures the relative toxicity of stomach poisons. The writer does not believe, however, that this is the only possible point of view.

The speed of toxic action of a stomach-poison is determined by the rate of the whole chain of physical and chemical events occurring from the time the poison enters the stomach until the insect dies, and the rate of the chain of events is dependent on the size of the dose and not on some fraction of the dose that may be supposed to be directly responsible for the death of the insect. If therefore equal doses of A and B produce the same effect, it seems logical to call them equally toxic *as stomach poisons*. Their relative toxicity by injection may be entirely different.

The first point of view is based on a conception of absolute toxicity, the value of which should be independent of the path of administration of the poison. Unfortunately absolute toxicity can not be measured. In the second point of view the power of the poison to reach susceptible tissues is considered a part of its potential toxicity under particular conditions. Thus it would not be inconsistent to find that the relative toxicity of poisons taken by mouth is different from that by injection.

If it is granted that the sandwich methods measure relative toxicity, which of the two is more suitable for a general survey of the relative toxicity of stomach poisons? The sandwich method for the determination of median lethal doses, being more practicable, is undoubtedly the better of the two. Median lethal doses can be used to compare the susceptibility of mammals and insects to the same stomach poisons and to estimate the least doses that would be required to kill any insect of a given weight. The sandwich method, however, is far from perfect for the determination of the relative toxicity of stomach poisons. It is seasonal and laborious. The ideal method would make possible a rapid oral administration of predetermined doses to an insect available throughout the year.

Conclusions

The toxicity of sodium fluosilicate to the fourth-instar silkworm ranges from 1 to 2 times that of acid lead arsenate, depending on the criterion of toxicity. Sodium fluosilicate incapacitates the silkworm faster than does acid lead arsenate, but the latter may kill the whole larva more rapidly than the former.

Methods in which insects are permitted to consume freely unknown quantities of poisons are unsuitable for the determination of the relative

toxicity of stomach-poisons because the observed effects, being usually produced by unequal mean doses, are not comparable. The sandwich method for the estimation of median lethal doses is the most practicable quantitative method so far proposed. Although the reliability and general significance of its results are satisfactory, it should be replaced by a less laborious method permitting the rapid oral administration of predetermined doses to an insect available throughout the year.

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PRESIDENT T. J. HEADLEE: The next paper is by S. Marcovitch and W. W. Stanley.

TWO ARSENICAL SUBSTITUTES

By S. MARCOVITCH and W. W. STANLEY, *Agricultural Experiment Station, Knoxville, Tennessee*

ABSTRACT

Among the fluorine compounds, cryolite and barium fluosilicate offer the most promise at the present time of meeting the requirements of an arsenical substitute. They are highly toxic to insects and reasonably safe on foliage. Barium fluosilicate is somewhat more toxic to insects than cryolite, and both materials when used at the rate of one pound to 50 gallons of water gave excellent control of the bean beetle. These materials may also be used as a dust on tobacco for the tobacco hornworm and flea beetles, and on beans for the bean beetle. Fish oil materially aids the sticking qualities of both cryolite and barium fluosilicate.

The need for an arsenical substitute is now clearly recognized by fruit and truck growers. Among the many fluorine compounds tested, both cryolite and barium fluosilicate appear to meet the requirements of toxicity, freedom from foliage injury, and availability.

Properties and Reactions

Cryolite. Cryolite occurs as a native fluoride of aluminum and sodium in Greenland. More than 10,000 tons are shipped annually for use in the manufacture of aluminum, the fused mineral being used as the bath for the electrolysis of alumina to the metal. Cryolite is also used in the manufacture of opaque white glass, in the enameling of ironware, and as a flux in the manufacture of white Portland cement. The natural cryolite when ground is a heavy powder and not well adapted for insecticidal purposes.

A synthetic powdered form is now available in commercial quantities that is light, very uniform in composition, and with a solubility of one gram to 1,639 parts of water. In water the artificial cryolite gave a pH of 6.2. One gram of the material required only 1½ c.c. 1/10 N. NaOH for neutralization, showing a very small soluble acid content.

The average analysis of the synthetic cryolite as submitted by Jungmann and Co. is as follows:

Sodium aluminum fluoride	98.20 per cent
Silica	.74 "
Sodium sulphate	.36 "
Iron oxide	.06 "
Moisture	.64 "

Several methods are known for making artificial cryolite—$Al_2F_6.6NaF$. Howard[1] used aluminum fluoride, ammonium fluoride, and salt, in accordance with the following reactions:

$$Al_2F_6+6NH_4F+6NaCl=Al_2F_6.6NaF+6NH_4Cl$$

Cryolite is readily decomposed by acids and alkalies. With lime, sodium aluminate and calcium fluoride is formed, as follows:

$$Al_2F_6.6NaF+6Ca(OH)_2=3Na_2O.Al_2O_3+6CaF_2+6H_2O$$

Barium Fluosilicate. Barium fluosilicate is not a commercial chemical at present, but due to its promising insecticidal properties several manufacturers have expressed a willingness to supply any demand that may arise. The principal virtue of barium fluosilicate lies in its low solubility (1–3750) and consequent freedom from excessive foliage injury. A saturated solution shows a pH of 3.4. One gram of material will require 110 c.c. of 1/10 N NaOH for neutralization.

[1]Howard H. Process of Making Artificial Cryolite. U. S. Patent No. 1,471,555.

In general, barium fluosilicate will react like sodium fluosilicate, but at a slower rate of speed. Barium fluosilicate may be made from by-product fluosilicic acid or from sodium fluosilicate, both of which are abundant and cheap. At the present writing barium fluosilicate is quoted at the same price as lead arsenate. If the demand for barium fluosilicate should increase, large-scale production would undoubtedly effect economies in manufacture.

The Question of Toxicity

Melanoplus femur-rubrum was employed to determine comparative toxic values. One gram of the chemical was used with 50 grams of bran. Within 30 hours, sodium fluosilicate gave 100 per cent mortality; barium fluosilicate 95 per cent; cryolite 20 per cent, and magnesium arsenate none.

Tests with other insects point unmistakably to barium fluosilicate as being much more toxic than cryolite when used against full-grown insects. One would be led to believe that correspondingly better results would be obtained in large-scale field tests against the bean beetle. The experimental work revealed little difference between barium fluosilicate and cryolite when used as a spray at the rate of one pound to 50 gallons of water for the bean beetle.

In small-scale experimental tests, differences in toxicity largely disappear as the dosage is increased. In the field, much more poison is used than is usually necessary, so that results do not vary as much as in the laboratory.

The poisoning operations with the bean beetle are conducted against the very small larvae, often not more than a day or two old. The young stages of insects are more easily killed and require much smaller amounts of poison than mature forms. In either case the large-scale operations to obtain practical control provide more material than will barely kill the insects. With the arsenicals an analogous situation exists. Paris green is known to be much more toxic than lead arsenate, yet the latter will give better control because of other factors, such as density and adhesiveness.

In the determination of the value of an insecticide several factors must be considered, among them being dosage, adhesiveness, toxicity, the nature of the insect employed, and freedom from foliage injury.

Effect on Foliage

The causes of foliage injury by chemicals are among the least-known phenomena in spraying and dusting plants. In general, materials that are readily soluble in water are more apt to burn. Sodium fluosilicate,

with a solubility of 1–154, is more likely to burn than calcium fluoride, with a solubility of 1–25,000. On the other hand, a highly insoluble material shows poor toxicity. For best results a material should be sufficiently soluble in the digestive tract of the insect to kill, and yet not injure foliage. The margin of safety is so small that among the host of chemicals known, only a few come near meeting the requirements. The work to date indicates that cryolite, with a solubility of 1–1,639, and barium fluosilicate, with a solubility of 1–3,750, falls within the safety zone. The past summer's work with these materials when used at the rate of one pound to 50 gallons of water on bean foliage revealed not a single instance of burning. Used as a pure dust at the rate of 6 to 12 pounds per acre, these materials were likewise safe on beans. When they were used in amounts greater than 20 pounds per acre some foliage injury was observed on beans. Since excellent control was obtained with only six pounds of pure dust per acre, the larger amounts are wasteful. If a machine is not available for dusting small amounts per acre, these materials may be mixed with a dilutent, such as lime or fuller's earth.

Different plants vary in their susceptibility to burning by fluorine compounds. Cotton seems to be the most resistant, followed by beans, cabbage, apple, potatoes, tobacco, cucumbers, peanuts, peach, and smartweed. No injury was observed from five weekly dustings on tobacco with either cryolite or barium fluosilicate when used at the rate of six to ten pounds to the acre. A few peach trees were sprayed with these materials at the rate of one pound to 50 gallons of water. Six weekly applications showed no visible foliage injury.

Fish oil, now used with lead arsenate as a sticker, was also found to be a very decided aid to the adherence of cryolite or barium fluosilicate. No foliage injury was noticed from it except when the insecticides were were used in amounts larger than were necessary.

Field Tests Against the Mexican Bean Beetle

Magnesium arsenate, calcium arsenate, cryolite, and barium fluosilicate were used at the rate of one pound to 50 gallons of water on 1/40-acre plots. Beginning May 17, five sprays were applied. All of these materials gave excellent control. Neither cryolite nor barium fluosilicate produced any burning whatsoever. The May 27th spray of calcium arsenate, however, caused considerable foliage injury, while a similar type of injury was encountered later in the season with magnesium arsenate. Our observations showed that this arsenical injury usually took place when the spray was applied just before the beans began to blossom.

Counts were made of the larvae present on June 15. The sprayed plots showed an average of 15 larvae per 3 feet of row, while the checks had 72 larvae. The sprayed rows yielded 10 pounds of green beans to the row, while the untreated rows yielded 6½ pounds.

The insecticides applied in the dust form also gave good control. The chief difficulty encountered was in getting the dusts on the underside of the leaves. All of these experiments were repeated on a large plot of beans nearly two acres in size. Substantially the same results were obtained. Space does not admit of our giving all the details, which will be published elsewhere. The best control among the dusts was obtained with barium fluosilicate when used pure at the rate of six pounds to the acre.

With a power sprayer, the cost of spraying an acre of beans runs between $1.30 and $1.75 for one application. With a bucket pump or a small three-gallon compressed-air sprayer, the cost approximates $2.40 when standard insecticide materials are used. Dusts applied with a rotary hand duster cost $1.50 per acre. Usually three sprays or four dust applications are necessary to give good control.

Experiments for the Control of the Tobacco Hornworm

The usual recommendations for the control of the tobacco hornworm (*Protoparce sexta*) consist of dusting with lead arsenate at the rate of five pounds per acre. Since tobacco growers are showing an interest in an arsenical substitute on tobacco, we gave both cryolite and barium fluosilicate a trial. We used cryolite, barium fluosilicate and potassium fluosilicate alongside of lead arsenate in four different plots. From the check plot we picked off 116 worms, from lead arsenate 5, cryolite 2, barium fluosilicate 8, and potassium fluosilicate 15. The potassium fluosilicate was lumpy and did not dust well. All of these materials gave good control and no foliage injury when used at the rate of six pounds per acre. Seven applications were made in order to test for foliage injury (Table 1).

Table 1. Tests of Insecticides Against the Tobacco Hornworm

(*Protoparce quinquemaculata*)

Material Used	Rate of Application	Date of Application	Degree of Infestation No. of Larvae	Foliage Injury
Lead arsenate.....	6 lbs. per acre	July 6–13–20–26–Aug. 2–9–16	5	None
Cryolite.....	"	"	2	"
Barium fluosilicate...	"	"	8	"
Potassium fluosilicate (by-product).....	"	"	15	"
Check.....			116	

The Tobacco Flea Beetle

One of the most troublesome insects in the tobacco bed is the tobacco flea beetle (*Epitrix cucumeris*), because of its potentialities in carrying diseases. These tiny pests are difficult to control, since the arsenicals are not readily eaten. In order to keep them in subjection Paris green must be resorted to, mixed with arsenate of lead.

Since flea beetles have the habit of licking their feet and cleaning themselves, and as sodium fluosilicate was found especially effective against insects with these habits, we made tests with cryolite and barium fluosilicate. In cage tests barium fluosilicate killed 92 per cent within 24 hours, while cryolite killed 77 per cent and lead arsenate 23 per cent (Table 2). A single application of barium fluosilicate in the field was observed to give a very material reduction in the number found on the plants. Since cryolite and barium fluosilicate will also control the hornworm, these materials show marked promise as tobacco insecticides.

Table 2. Cage Tests of Insecticides Used as Dusts Against the Tobacco Flea Beetle, *Epitrix cucumeris*, Showing Per cent Dead in Hours

Material	16 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
Barium fluosilicate	87	92.4	96	100	100
Cryolite	58	77	86	96	97
Lead arsenate	14	23	36	48	60
Tests with the Cucumber Beetle, *Diabrotica vittata*					
Barium fluosilicate	80	100			
Cryolite	26	52			
Lead arsenate	19	35			

The Cucumber Beetle

Cage tests with the cucumber beetle (*Diabrotica vittata*) showed 100 per cent mortality with barium fluosilicate in 24 hours; cryolite gave 52 per cent, and lead arsenate 35 per cent. No foliage injury was obtained with these materials when used lightly at the rate of six pounds to the acre.

Mr. M. V. Anthony carried out the experimental work on tobacco insects, and assisted in the spraying and dusting experiments for the bean beetle.

Summary

The demand for an arsenical substitute has arisen from various sources, such as the truck and apple growers, who are harassed with the residue problem. Muck soils will decompose the insoluble arsenates, making the ground unfit for growing plants.

Among the fluorine compounds which best meet the requirements of a stomach poison, cryolite and barium fluosilicate offer the most promise at the present time.

These materials have a comparatively low solubility, and are therefore reasonably safe on foliage. They may now be obtained in commercial quantities at about the same price as lead arsenate.

Both cryolite and barium fluosilicate are highly toxic to insects. In small quantities, such as might occur on plants, fluorine compounds, as far as known, are not dangerously poisonous to man.

For adult insects, barium fluosilicate is more toxic than cryolite. Both materials gave excellent control of the Mexican bean beetle when used as a spray at the rate of one pound to 50 gallons of water.

At the rate of six pounds to the acre, both cryolite and barium fluosilicate used as a dust gave no foliage injury on beans. Thirty pounds or more to the acre produced moderate burning. Five weekly dustings on tobacco produced no foliage injury with either material, and controlled the hornworms and flea beetles.

Fish oil used at the rate of 25 per cent of the weight of cryolite, or barium fluosilicate very decidedly aided the sticking qualities.

Both cryolite and barium fluosilicate, used in the dust form, at the rate of six pounds to the acre, gave very good control of the bean beetle. These materials were also used successfully when mixed with two parts of lime.

MR. W. E. HINDS: I should like to ask if any tests were made on corn.

MR. W. W. STANLEY: We tried several tests on corn this summer. We used both cryolite and barium fluosilicate to determine what degree of control might be found on the corn earworm. Both chemicals caused slight burning to the tassels, but no appreciable injury to the foliage. Barium fluosilicate gave somewhat more injury.

PRESIDENT T. J. HEADLEE: Next is a paper by Ralph H. Smith.

A BRIEF REPORT ON THE TANK-MIXTURE METHOD OF USING OIL SPRAY

By RALPH H. SMITH, *Associate Entomologist, University of California, Citrus Experiment Station*

ABSTRACT

With over 35 brands of highly refined oil emulsions on the market for use in the spraying of citrus trees in southern California, backed in general by methods of "high-pressure" salesmanship, and with widely variable results in insect control and injury to trees, a definite need existed for a formula whereby the grower who so desired could use a spray of known composition. Pursuant to this need investigations showed that, when the type of oil best suited for citrus spraying is used, the principal quality of the spray mixture is that which relates to the quantity of oil deposited and the uniformity of the oil coverage. Tests showed that it is entirely

practicable, with modern orchard sprayers, to maintain a uniform mixture of water, emulsifier, and pure oil, added separately to the spray tank, by using large-sized blades on the agitators and increasing the speed of the agitator shaft to about 225 r.p.m. By dyeing the spray oil and placing a piece of heavy-walled glass tubing at each end of the spray hose, one between the spray tank and the hose and the other between the hose and the spray nozzle, the fact was determined that the oil globules do not coalesce or float out to any material extent in passing through the spray hose. Microscopic studies of samples taken from the spray tank and from the spray nozzle showed that even though globules of relatively large size might pass through the hose, these are broken into very small globules, quite comparable to those in proprietary emulsions, as a result of being forced through the nozzle under a pressure of 300 pounds.

Studies on the quantity of oil deposited on glass and citrus leaves, 25 square inches being used as the unit of area, showed that certain proprietary emulsions deposited three times as much oil as others. The average amount deposited on the glass was 21 milligrams. Tests with the tank mixture, using calcium caseinate spreader at the rate of ½ pound to 100 gallons of water, showed a deposit of 22 milligrams of oil. All tests were made with two percent of actual oil in the spray.

Introduction

The term "tank mixture" is applied to the method of using oil spray in which the water, emulsifier and pure oil are added separately to the spray tank and a uniform mixture maintained by the agitators. The method has been used for nearly four years at the Citrus Experiment Station in experimental tests in comparison with several of the leading proprietary emulsions, and in regular control work on the Station property. In addition, during the past two years, it has received practical testing by growers in spraying over 300 acres of citrus trees. It appears to have an important place in the spraying of citrus trees under the conditions of pest control occurring at the present time in southern California. Whether or not it is applicable to the dormant and summer applications of oil sprays to deciduous trees, or merits recommendation for general use, remains to be determined.

The method was originally used in experimental tests to determine the value of different kinds of spray oils. The results obtained by using the oils in this manner were more dependable, it was believed, than if the oils were emulsified before adding them to the spray tank. The latter procedure carried the possibility of variable results being caused by differences among batches of emulsions. Furthermore, in many tests it was desired to entirely dispense with the use of emulsifiers. Subsequent observations on the widely variable results in insect control and injury to trees, which was especially apparent in 1928 when over 35 different brands of proprietary oil sprays were on the market, led to the investigation and results briefly reported herein.

The insecticidal efficacy of oil sprays and the effects of oil sprays on trees, insofar as the oil is concerned, are governed by (1) the purity of the oil, (2) the viscosity and volatility of the oil, and (3) the quantity of oil deposited on the insect and tree. The first two factors are measurable and quite well understood at the present time.

The third factor is the one with which this paper is chiefly concerned. Its importance is fundamental. The original purpose underlying the discovery of kerosene emulsion 50 years ago was to provide a way to accomplish a uniform coverage of oil over the trees. That apparently is the only reason why spray oils are made into emulsions at the present time.

SPRAY-TANK AGITATION. The first requirement for assuring a uniform coverage of oil is that the oil be uniformly distributed through the water in the spray tank. Much emphasis was once placed on the danger of the oil rising to the top of the water, due to improperly-made emulsions and to emulsions "breaking" when mixed with water in the spray tank. However, a study of many sprayers in practical operation and in experimental tests has shown conclusively that it is a simple and entirely practicable matter to maintain a uniform mixture when pure oil is poured into the water in the tank.[1] A brief statement of the essential facts will be sufficient here.[2]

In the case of the Bean, Deming, Hardie, Hayes, Karth, Mount Gilead, and Ward-Love sprayers, the agitator shaft is approximately 7½ inches from the bottom of the tank. Waiving discussion of minor factors it may be said that if the agitators, whether two-bladed or three-bladed, have blades approximately 6½ inches long and 4½ inches wide with a pitch of 40 degrees, and are placed approximately six inches from the ends of the tank and one foot apart on the agitator shaft, and the latter has a speed of 225 r.p.m., a uniform mixture of pure oil and water can be maintained in any tank of ordinary form, either half-round or elliptical, up to 400 gallons in capacity. Thus equipped, the tank may be filled with water, pure spray oil then poured on the top, and after the agitator has run for two minutes (tests have not been made

[1]The mixture of pure oil and water is discussed because this represents the most adverse condition, as pertains to agitation, that would be confronted in practical spraying. As shown in the articles on spray-tank agitation, cited in the accompanying footnote, the addition of a spreader or emulsifier, as is required in the tank-mixture method, greatly facilitates the ease with which a uniform mixture can be maintained.

[2]For further information concerning agitation in spray tanks, see JOUR. ECON. ENTOM. December, 1929, pp. 929–934.

to determine the minimum time) the oil will be uniformly dispersed in small globules throughout the water.

One test with a "Friend" sprayer, which has a type of agitator that is different from the sprayers aforementioned, will be described. The data concerning the sprayer are as follows: Capacity of tank 300 gallons, speed of agitator shaft 200 r.p.m., blade of front agitator 9 inches long and 6 inches wide, blade of rear agitator 8½ inches long and 3 inches wide. The tank was filled with water and three gallons of oil poured on the surface. The agitator was then started and at the end of fifteen seconds a uniform mixture was produced.

QUANTITY OF OIL DEPOSITED. The second requirement of an oil spray, as pertains to the uniformity of the coverage of oil, is that the physico-chemical composition of the mixture be such that in case one part of a tree is drenched in spraying and another part is moderately sprayed, the deposit of oil will not be excessive on the one part nor insufficient on the other. The importance of this factor is emphasized by the results of the present study which show that in the case of the oil emulsions generally used in summer spraying, the deposit of oil tends to build up as spray is applied in excess of the amount required to produce the initial film, and that the quantity of oil deposited in the initial film, as well as the building-up tendency, varies greatly among emulsions. Certain experiments bearing on this subject will be briefly discussed.

Thin window glass was cut into sections 3½ inches wide and 7 inches long, the area of one surface being regarded as 25 square inches. An extensive set of tests was made in the laboratory, in which spray was applied by means of an atomizer, under three pounds constant air pressure, to one surface of each section. Four sections were used in each test. By weighing before spraying and after spraying when the water had evaporated, the quantity of oil deposited was determined. This work was supplemented by applying the spray with a spray gun under 300 pounds pressure, with many adaptations designed to bring out the importance of different variables and the factors controlling them. Tank-mixtures with spray oils of different viscosities and with different emulsifiers were tested in comparison with proprietary emulsions. The spray in each test contained two per cent actual oil. The average amount of oil deposited in laboratory tests with 12 different proprietary emulsions[2] was 21 mg. per section. Four emulsions deposited less than 13 mg.

[2]The proprietary emulsions were true emulsions; that is, none was a miscible oil. They contained from 80 to 90 per cent oil. The oils were of the highly-refined type, being above 84 per cent in unsulfonated residue, and ranged from 50 to 100 seconds Saybolt, in viscosity.

per section and five deposited more than 25 mg. The lowest was 11 mg. and the highest 33 mg. The tank-mixture consisting of pure spray oil thoroughly agitated with water containing calcium caseinate spreader at the rate of ½ pound to 100 gallons, deposited 22 mg. The oil used in this test had the same specifications as that contained in a widely used proprietary emulsion, the viscosity being 50 seconds Saybolt and the unsulfonated residue 94 per cent. Tests similarly made with orange leaves showed that considerably more oil per unit of area was deposited on the leaves than on the glass and that the building-up tendency was more pronounced on the leaves. The fact was determined that less oil is deposited on objects close to the spray nozzle than on those several feet away. The intermittent exposure of a surface to the spray, such as results from playing the spray nozzle back and forth, accentuates the building up of the deposit. Spraying a surface for the second time immediately after the water from a previous application has evaporated results in approximately doubling the deposit of oil.

Size of Oil Globules. Considerable attention heretofore has been given to the size of the oil globules in spray emulsions, the supposition being that the quality of the spray is related to the size of the globules. Certain experiments relating to this subject will be of interest.

Pure spray oil ranging above 90 per cent in unsulfonated residue, and different proprietary emulsions containing this kind of oil, were dyed with oil-soluble red dye in order that the globules could be readily observed. A piece of heavy-walled glass tubing was fastened to each end of a 50-foot spray hose, one piece being attached between the hose and the spray tank and the other between the hose and the spray gun. In this manner it was possible to observe the character of the spray mixture during agitation and during passage through the hose. The study also involved taking samples from the tank and from the nozzle in 500 cc cylinders and the studying of microscopic mounts. The tests were made with a 200 gallon tank equipped with four agitators each having two blades 6½ inches long and 4½ inches wide, and turning at 225 r.p.m.

The globules of the tank-mixture, as observed both in the tank and in the glass tubes, were somewhat larger than those of the spray mixture containing the proprietary emulsions but this difference was scarcely distinguishable in samples taken from the spray nozzle under a pressure of 300 pounds. As a result of various modifications in the method of testing, the fact was determined that even though globules of comparatively large size might pass through the hose, these are

broken into very small globules under the effect of the pressure with which they are forced through the nozzle. With a pressure of 300 pounds the largest sized globules from the tank-mixture of pure oil and water were no larger and no more numerous than those from the proprietary emulsions.

KIND AND AMOUNT OF EMULSIFIER. Preliminary tests at once indicated that the most important factors affecting the quantity of oil deposited were the kind of emulsifier and the amount present in the spray. Extensive tests have been made on this phase of the study but because of certain large variations in measurements, resulting apparently from imperfect technique and apparatus, only a few general statements can be made at this time. Soaps cause much less oil to be deposited than do other emulsifiers used in equivalent amounts. In the case of certain emulsifiers, small amounts, two ounces or less per hundred gallons of spray, result in a heavier coating of oil than occurs when no emulsifier is used at all. Certain emulsifiers or spreaders, even when used in amounts which give good spreading with other sprays, may actually result in more oil being deposited than is deposited by a mixture of pure oil and water.

CONCLUSIONS. Taking into consideration (1) the large number of proprietary oil emulsions on the market in southern California and the variable results experienced in injury to trees and insecticidal effectiveness and (2) the experimental data mentioned in this paper which show that, under like conditions, certain emulsions may deposit three times more oil than others, there seems to be ample ground for concluding that a definite need exists for a method whereby the grower who so desires can make his own spray. The investigation, at present, indicates that the tank mixture meets this need better than the formulae heretofore suggested for "home-made" oil sprays. The method is especially suitable under conditions in this region where nearly all of the spraying is done by licensed commercial spray operators, under supervision of County Agricultural Commissioners. The fact that a saving of about 50 per cent of the present cost of emulsions is made possible, is also worthy of consideration.

The author is cognizant of the fact that within the past 10 years authorities on spraying have very generally abandoned home-made formulae in favor of standardized proprietary products. He is in full accord with that tendency. The highly-refined oil emulsions represent an exception, however, in that they are not standardized with regard to the factors discussed in this article. Until they become standardized

to a greater degree than at present, the tank-mixture method may properly have a place in recommendations for the spraying of citrus trees. Should the continuation of this investigation produce further evidence to substantiate the proposition that the making of oils into concentrated emulsions is unnecessary, the reason for the exception will, of course, be further strengthened.

PRESIDENT T. J. HEADLEE: I would like to ask Mr. Smith whether the toxicity of the oils to foliage is dependent upon the amount left upon the foliage more than upon other factors.

MR. R. H. SMITH: In spraying citrus trees in California, we advise using oils that are 90 per cent or above in unsulfonated residue. When injury results from the use of an oil of that purity, such injury is due either to the oil being too heavy, that is, too non-volatile, or to too much oil being deposited by the emulsion. The excessive amount of oil deposited is responsible for many cases of injury.

PRESIDENT T. J. HEADLEE: Our own experience indicates that that position is extremely well taken. The amount of oil deposited, other things being equal, is perhaps the dominant factor.

MR. ANTHONY SPULER: I would like to ask Mr. Smith if the amount deposited does not depend on the length of time the mixture is sprayed on a tree.

MR. R. H. SMITH: I did not have time to discuss the factors relating to the application of the spray, which affect the amount of oil deposited and the tendency of the oil film to build up, but those tests with the spray machine were done in many different ways. We exposed surfaces intermittently to the spray. Other times we would spray, shake the spray off and spray again. In other cases we would spray and let the water evaporate, and spray again.

There are many factors that have to do with the building up of the oil film. I cannot discuss them completely, but will say that in our work we found by using one-half pound of calcium caseinate spreader to 100 gallons of water there was no greater tendency for the tank-mixture to build up than was the case with the best of the proprietary oil emulsions in general use.

PRESIDENT T. J. HEADLEE: The next paper is by A. L. Strand.

A PHASE OF INSECT RESPIRATION IN RELATION TO THE TOXICITY OF CONTACT INSECTICIDES

By A. L. STRAND, *St. Paul, Minn.*

(Withdrawn for publication elsewhere)

MR. W. C. O'KANE: The paper by Mr. Strand, the elaborate and fine work he is doing up there, emphasizes to all of us the extraordinary complexity of many unknown and very valuable factors in economic entomology. If we had 15 or 20 men to work on insect respiration, well trained men, at the present time they would have five or ten years' work ahead of them to find out the things that we as entomologists really ought to know. I wish there were more in the same kind of work.

PRESIDENT T. J. HEADLEE: The next paper is by D. M. DeLong, W. J. Reid, Jr., and M. M. Darley.

THE PLANT AS A FACTOR IN THE ACTION OF BORDEAUX MIXTURE AS AN INSECTICIDE

By D. M. DELONG, W. J. REID, JR., and M. M. DARLEY,[1], *U. S. Bureau of Entomology, Columbus, Ohio*

ABSTRACT

Tests with inverted petri dishes covered with capping membranes and containing sugar solutions or expressed plant juices showed that copper could be dissolved from Bordeaux mixture residues sprayed on the capping membranes. Distilled water, used in the same manner, gave negative results. Rain-water collected over a period of approximately three months and which had passed through glass funnels containing filter papers covered with Bordeaux mixture residue gave negative chemical tests for copper. Rain-water collected from plants sprayed with Bordeaux mixture and leaves containing Bordeaux mixture washed in water gave chemical tests for copper. Rain or dew is not necessary on the Bordeaux mixture sprayed plant in order to kill leafhoppers.

Refractometer readings of sprayed and unsprayed plant juices showed that, as a rule, in vigorous growing plants the solid (sugar) content of the sprayed plants was lowered for about two days below that of the unsprayed plants but soon became higher and with few exceptions usually remained higher than that of the unsprayed plants for about two weeks.

[1]Suggestions, advice and criticisms regarding methods and results have been offered by Dr. N. F. Howard, U. S. Bureau of Entomology, Columbus, Ohio; Dr. Edward Mack, Department of Chemistry, Ohio State University; Dr. R. C. Burrell, Department of Agricultural Chemistry, Ohio State University; and by Drs. B. S. Myers, Lois Lampe, and G. W. Blaydes and Mr. K. E. Wright of the Botany Department, Ohio State University.

Previous work performed by many workers upon Bordeaux mixture as a fungicide or insecticide has shown certain definite facts regarding its use or action which should be stated very briefly as an introduction to the experimental data presented herein. A spray of Bordeaux mixture when dried is practically insoluble in water, and if permitted to settle as a precipitate in a spray solution there is practically no copper in the supernatant fluid (*2*) (*11*). But in order for it to become effective as either a fungicide or an insecticide it apparently must be rendered soluble. The question of how this is accomplished on the plant has been the subject of considerable experimental work and discussion. Previous work, especially by Crandall (*6*), has pointed to atmospheric conditions or meteoric water as the most important agents in rendering copper soluble from a Bordeaux mixture spray film. This conclusion was reached by testing water from sprayed apple trees. On the other hand Clark (*4*) has stated that the epidermis of the leaves, although protected by a cuticle, is well known to be more or less permeable to the dissolved substances occurring in the cell sap, particularly along the union of the epidermal cells. On this basis he explains that the dew on the outside and the cell sap within cause exosmosis to take place and the copper hydroxide to become at least partially soluble.

It is known that sugar solutions will readily dissolve copper from Bordeaux mixture. With this fact as a basis, a series of experiments was performed using petri dishes and covering them with capping membranes (*3*) which were sealed over the open end. Equal volumes of distilled water, tap water, sap expressed from bean plants, and sap expressed from potato plants, as well as solutions of dextrose, sucrose, and other sugars varying from 1 to 15 per cent in strength were placed in individual petri dishes before the membranes were sealed over the top. The membranes were then sprayed with freshly made Bordeaux mixture and permitted to dry. The petri dishes were thereupon inverted so that the solution inside was kept in contact with the Bordeaux mixture covered membranes. In two or three days the membranes were removed and the liquid tested for copper. The distilled and tap water gave negative copper tests, but in every case where sugar was present in the water positive tests were obtained, and the percentage of copper varied directly with the percentage of sugar in the solution. The plant juices of both bean and potato gave strong positive tests showing that the juices of these plants can readily dissolve copper in some form from Bordeaux mixture residue and absorb it through a permeable membrane. A similar condition caused either by sugars or organic acids probably occurs in sprayed plants.

RAIN-WATER TESTS OF BORDEAUX RESIDUE ON FILTER PAPER. In order to test the solubility of Bordeaux mixture under out-of-doors conditions with the plant eliminated as a factor, heavy applications of Bordeaux mixture were made to filter papers placed in glass funnels. The stem ends of these funnels were placed in stoppered glass bottles and these were placed in the open where they would be exposed to the elements. During a period of approximately three months several liters of water were collected from summer rains and dew which passed over the Bordeaux-mixture residue on the filter papers. By testing this water for copper and using a test[2] that would readily show a 1–50,000 solution, all tests were negative or doubtfully positive even when the water was evaporated and the solution rendered more concentrated. This agrees with results obtained by Crandall (*6*) while using glass evaporating dishes and shows rather conclusively that rain-water alone, in appreciable quantities, will not dissolve copper from Bordeaux mixture.

SOLUBILITY OF COPPER FROM BORDEAUX MIXTURE IN RAIN WATER FROM SPRAYED LEAVES. In rain-water collected from plants which were previously sprayed with Bordeaux mixture, soluble copper was detected very readily and a strong positive reaction was obtained from the mixture with potassium ferrocyanide. This same reaction can be obtained by washing the sprayed leaves in distilled or tap water. The reaction in this case has been obtained within two or three days after the plants were treated. Thus copper can be dissolved readily from Bordeaux mixture residue upon plants but can not be dissolved from residues of similar material on other objects or materials. The plant must therefore be recognized as an important factor in the solubility of copper from Bordeaux mixture. Precipitation is apparently not important if we may judge from previous experiments and observations. Leafhoppers will die in a short time upon plants which have been sprayed with Bordeaux mixture and protected from rain and dew. Furthermore, recent tests have given positive copper reactions in plant juices which were expressed from plants sprayed with Bordeaux mixture where the residue was removed by a 2 to 5 per cent acetic solution before the juice was expressed. These plants also were protected from rain or dew, and some factor other than precipitation must have rendered the copper soluble. Plants under exactly the same conditions but not treated gave negative copper tests by the same method. It has been observed (*7*) that death of the feeding leafhopper occurs

[2]Both hydrogen sulphide (H_2S) and potassium ferrocyanide (K_4 Fe $(CN)_6$) were used.

much sooner on the sprayed surface of a leaf than upon the unsprayed surface of the same leaf. Although no method has been devised for obtaining data, it is quite probable that the Bordeaux-mixture residue becomes more soluble at the point where the mouthparts puncture the leaf for feeding. The plant juice is undoubtedly in closer proximity at these points with the residue of Bordeaux mixture, at least in small quantity, and this plant juice has been proved to dissolve copper readily from such residue when in contact with it.

The plant is therefore thought to be an essential factor in rendering copper soluble when it is applied on plant tissue as a Bordeaux mixture spray.

Refractometer Readings of Plant Sap from Sprayed and Untreated Plants. The present investigation was undertaken to test, if possible, the effect of Bordeaux mixture spray upon the sap of treated plants. In order to accomplish this, refractometer readings were made daily on sap from both treated and untreated plants. The leaves of both were washed in the same solutions in order to remove spray residue when present, then after draining thoroughly they were pressed in a hydraulic press, using a uniform pressure. The plant sap was then tested for solids by the Abbe refractometer (Table 1). These percentages of solids are usually called sugars since the percentages of the other combined solids present are extremely small.

When daily examinations are made, these readings usually show that in both bean and potato plants there is a difference in the refractive index of treated and untreated plants when they are of exactly the same age and are taken from adjacent rows where soil and atmospheric conditions are the same. Numerous examinations over periods of several days after treatment indicate that as a rule the sugar content of the treated plants is lowered, for one or two days after treatment, below that of the untreated plants. The sugar content, however, soon rises in the treated plant above that of the untreated and usually remains above for a period of two or three weeks, occasionally dropping below for a short period. These data are shown in graphic form in Figures 41 and 42. Both the age of the plant and the rate of transpiration may affect this sugar content to some extent and may change the percentage or degree of difference between treated and untreated plants. These conclusions were based upon some 26,000 readings taken during June, July, August, and September. Duggar and Cooley (*8*) have shown that in potted plants the transpiration rate is higher upon treated than upon untreated plants.

TABLE 1. ABBE REFRACTOMETER READINGS OF PLANT SAP AND COMPUTATION OF SOLIDS (SUGARS)

Date Examined	Number of Days After Treatment	Untreated Potato			Treated Potato			Untreated Bean			Treated Bean		
		Aver. Refrac. Index Readings	Per cent Water Corrected to 20°C.	Per cent Solids	Aver. Refrac. Index Readings	Per cent Water Corrected to 20°C.	Per cent Solids	Aver. Refrac. Index Readings	Per cent Water Corrected to 20°C.	Per cent Solids	Aver. Refrac. Index Readings	Per cent Water Corrected to 20°C.	Per cent Solids
Aug. 6	1	1.3403	94.94	5.06	1.3398	95.24	4.76	1.3412	93.94	6.06	1.3420	93.74	6.26
7	2	1.3391	95.56	4.44	1.3384	96.06	3.94	1.3382	96.16	3.84	1.3390	95.66	4.34
8	3	1.3379	96.4	3.6	1.3382	96.1	3.9	1.3413	94.0	6.0	1.3401	94.8	5.2
9	4	1.3391	95.5	4.5	1.3395	95.2	4.8	1.3400	94.9	5.1	1.3428	93.1	6.9
10	5	1.3380	96.3	3.7	1.3390	95.6	4.4	1.3397	95.1	4.9	1.3405	94.6	5.4
12	7	1.3374	96.64	3.36	1.3378	96.34	3.66	1.3402	94.74	5.26	1.3413	93.94	6.06
13	8	1.3382	96.1	3.9	1.3382	95.6	4.4	1.3417	93.5	6.5	1.3410	94.3	5.7
14	9	1.3380	96.42	3.58	1.3393	95.52	4.48	1.3408	94.42	5.58	1.3420	93.72	6.28
15	10	1.3391	95.56	4.44	1.3390	95.56	4.44	1.3419	93.66	6.34	1.3419	93.66	6.34
16	11	1.3388	95.82	4.18	1.3408	94.52	5.48	1.3431	92.92	7.08	1.3438	92.52	7.48
17	12	1.3395	95.32	4.68	1.3418	93.82	6.18	1.3470	90.42	9.58	1.3454	91.42	8.58
19	14	1.3393	95.46	4.54	1.3400	94.96	5.04	1.3426	93.16	6.84	1.3438	92.46	7.54
20	15	1.3398	95.22	4.78	1.3407	94.52	5.48	1.3453	91.52	8.48	1.3450	91.72	8.28
21	16	1.3401	94.92	5.08	1.3403	94.82	5.18	1.3445	92.02	7.98	1.3448	91.82	8.18
22	17							1.3420	93.66	6.34	1.3425	93.26	6.74
23	18	1.3388	96.7	3.3	1.3388	96.7	3.3	1.3427	93.1	6.9	1.3429	93.0	7.0
24	19							1.3427	93.1	6.9	1.3425	93.2	6.8

Average refractive index readings were computed from 6400 readings; These are shown in the form of a graph in Fig. 41.
Per cent Water corrected to 20°C—were obtained from Tables 17 and 18, pp. 134–137, Cir. 44 U. S. Bur. Standards.

In very young or extremely old plants there is more fluctuation in the relative percentages of sugars, and the above-mentioned condition will frequently change from day to day. In vigorous growing plants of medium size the sugar content usually remains higher in the sprayed than in the untreated plant.

The present data obtained from refractometer tests are in agreement with the work of Cook (5), who found that in plants sprayed with copper the percentage of weight of the tubers compared to that of the vine is higher on treated than on untreated plants, the tubers being the natural outlet for the starch manufactured by the leaves. This stimulation of tuber growth and the relative increase in the weight of tubers are shown early in the development of the plant.

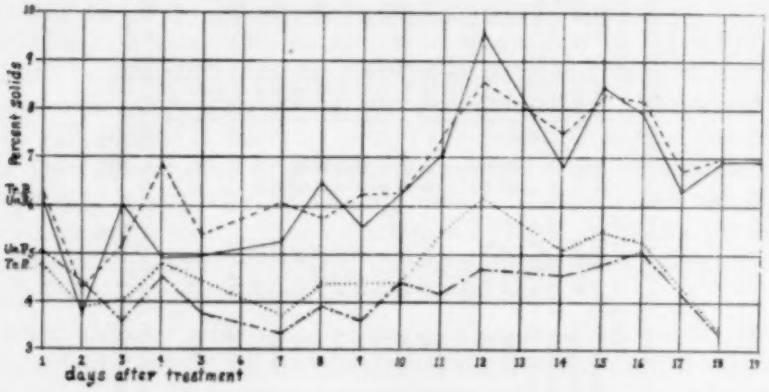

FIG. 41.—Graph showing untreated and treated bean and untreated and treated potato plants, indicating per cent of solids in plant juices. (Tr. B. = Treated Beans; Un.B. = Untreated Beans; Un.P = Untreated Potatoes; Tr.P. = Treated Potatoes.)

EVIDENCE FROM LITERATURE INDICATING ABSORPTION OF COPPER. There is no doubt that the plant is definitely affected by applications of Bordeaux mixture spray. Investigators, however, differ in their opinions concerning the degree to which this occurs and the way in which it is manifest. The great majority of data upon yields accumulated by scientific workers, over a period of 25 to 30 years indicate that the potato plant is stimulated in some way and there is greater production on treated plots even when fungous and insect enemies seem to be present in such small numbers as to cause no appreciable reduction in yield on the untreated plants. Babcock (1) finds this to be the case. Cook (5) states that as a rule potato tubers from Bordeaux mixture sprayed plots are higher in the percentages of solids, starch, and nitrogen

than are tubers from unsprayed plots. He also states that it is evident that the copper-sprayed plants generally gave an increased yield of tubers and that these increased yields followed the application of these sprays in seasons when no late blight was prevalent. The differences in yield could not be accounted for by the small number of insects present.

A few workers, on the other hand, claim that the crop is reduced in yield by Bordeaux mixture spray, and they support their belief by data. In some cases it is a well known fact that conspicuous injury and destruction of foliage occur. It is apparent that varied conditions such as different methods of Bordeaux mixture preparation, the time and number of applications, and climatic fluctuations are almost certain to give varying results. The evidence seems to indicate, however, that as a rule the plant is stimulated by applications of Bordeaux mixture.

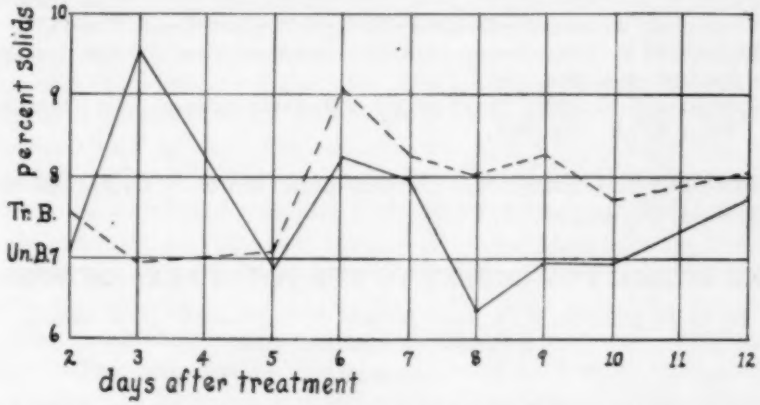

FIG. 42.—Graph showing untreated and treated bean plants, indicating per cent of solids in plant juice. (Tr. B = Treated Beans; UnB. = Treated Beans.)

Most workers have noticed that the potato foliage becomes darker green and seems more healthy in appearance when treated with Bordeaux mixture. Frank and Kreuger (*9*) have shown that the leaves are actually thickened and that the life of the plant is lengthened by Bordeaux mixture applications. The chlorophyll content is increased and correlated with this there is a rise in the assimilating capacity, more starch being formed. Lutman (*10*) found practically the same thing, and states that a small quantity of copper enters the leaf and that chemical combination takes place between the copper and the chlorophyll, this rendering the chlorophyll less soluble and less easily removed from the sprayed plant.

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PRESIDENT T. J. HEADLEE: The next paper is also by D. M. DeLong, W. J. Reid, Jr., and M. M. Darley.

THE TOXICITY OF COPPER TO THE POTATO LEAFHOPPER

By D. M. DELONG, W. J. REID, JR., and M. M. DARLEY,[1] *U. S. Bureau of Entomology, Columbus, Ohio*

ABSTRACT

Copper sulphate solutions of known strength containing 5 per cent sugars were fed to potato leafhopper (*Empoasca fabae* Harris) nymphs through capping membranes. Dilutions to and including a 1:6,500 (.0012 N) gave a rather high degree of toxicity. These nymphs lived for an average of 12 days upon a 5 per cent sugar solution and an average of three days upon distilled or tap water. The supernatant fluid from a 4–6–50 Bordeaux mixture obtained after two hours' setting, combined with 5 per cent sugar, gave a 14-day average survival. Roots of bean plants were placed in different dilutions of copper sulphate solutions, and leafhoppers were allowed to feed upon these plants. A high rate of mortality was obtained in these

[1]Suggestions, advice and criticisms regarding methods and results have been offered by Dr. N. F. Howard, U. S. Bureau of Entomology, Columbus, Ohio; Dr. Edward Mack, Department of Chemistry, Ohio State University; Dr. R. C. Burrell, Department of Agricultural Chemistry, Ohio State University; Drs. B. S. Myers, Lois Lampe, and G. W. Blaydes and Mr. K. E. Wright of the Botany Department, Ohio State University.

tests, and copper was found by chemical tests to be present in the plant juices of these leaves. Spray solutions of copper sulphate and of calcium hydroxide were used on different plants, and nymphs were placed on each of these. The copper-sulphate-treated plants showed considerable toxicity while the calcium hydroxide did not affect the leafhoppers.

A series of experiments performed in the summer of 1928 (*1*) indicated that the potato leafhopper[2] when feeding upon sprayed bean and potato plants obtained a toxic dose of copper from the plant sap. As a result of this investigation experiments were conducted during the summer of 1929 to determine, if possible, the toxicity of copper to leafhoppers, both through the medium of plant tissues and when obtained from known solutions directly through capping membranes.

FEEDING TESTS THROUGH MEMBRANES WITH DILUTIONS OF COPPER SULPHATE AND OTHER MATERIALS. Several series of tests were made with both adults and nymphs of the leafhopper to determine the toxicity of copper sulphate in solutions of various concentrations when the leafhoppers obtained the chemical by feeding directly through a membrane. Capping membranes were used for this purpose as well as feeding tubes similar to those used by Carter (*2*). The feeding solutions used in these tests were placed in small glass vials holding about 20 c.c. of liquid. The open end of each vial was covered with a membrane and this covered end fitted snugly in an opening in a straight-sided cork stopper so that the membrane was just flush with the stopper. This stopper, holding the vial, was placed in one end of a larger glass cylinder 5 inches long and 1½ inches wide, the membrane-covered end of the vial being inside the cylinder. The leafhoppers were then placed in the glass cylinder and a cheesecloth cover placed over the open end. By placing these feeding cylinders so that the source of light came through the membrane, the leafhoppers would move immediately to this spot and attempt to feed within a short time.

All dilutions of copper used for these tests were made from a stock solution marked a "1 to 100" strength and made by dissolving 1 gram of copper sulphate pentahydrate ($CuSO_4.5H_2O$) in 100 c.c. of water.

It had been determined previously that leafhopper nymphs lived for an average of 12 days on a 5 per cent solution of cane sugar, with a maximum survival of 32 days. When permitted to feed on distilled or tap water alone, the average period of survival was three days with a maximum of five days. The test in which this latter average survival was obtained might be considered a starvation-point test since very little, if any, food is obtained from distilled water. It was quite evident

[2] *Empoasca fabae* Harris.

that when leafhoppers were feeding on solutions of copper sulphate and died in about three day's time, the cause of death might have been starvation. Therefore, a 5 per cent sugar solution was used with each dilution of copper sulphate, thus making provision against death by starvation. A graph (Fig. 43) on which was recorded the average number of days survival when different strengths of copper sulphate solution were used in combination with sugar gives a curve showing relative toxicity. This curve is based on some 2600 records. Experimental data show in brief that the leafhoppers live on an average less than one day on dilutions of copper sulphate and sugar up to 1 to 300[3] (.0266N) inclusive and an average of two days on solutions of 1 to 500 (.0160 N) to 1–1,000 (.0080 N) inclusive. The average survival in days for greater

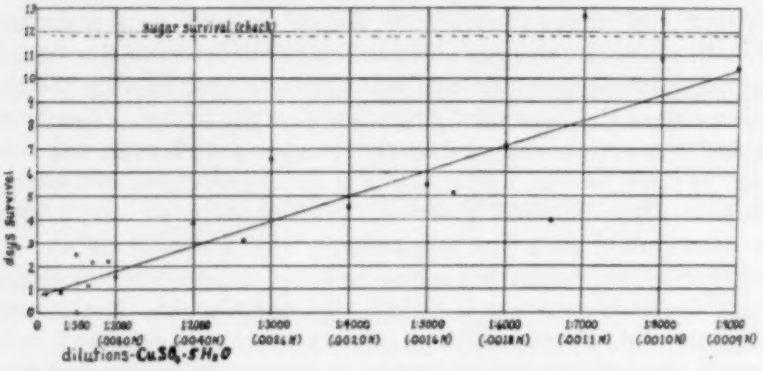

FIG. 43.—Graph indicating average days of survival of potato leafhopper nymphs which had fed upon copper sulphate solutions of different strengths combined with sugar.

dilutions, combined with sugar, was as follows: 3.6 days for a 1–2,000 (.0040 N) dilution; 6.7 days for a 1–3,000 (.0026 N) dilution; 4.6 days for a 1-4,000 (.0020 N) dilution; 5.5 days for a 1–5,000 (.0016 N) dilution; and 3.9 days for a 1–6,600 (.0012 N) dilution. Dilutions of from 1–7,000 (.0011 N) to 1–9,000 (.0009 N), although performed under somewhat lower temperatures than most of the preceding high dilutions, gave an average survival of 10 to 12 days.

TOXICITY OF COPPER IN BORDEAUX MIXTURE SOLUTION. Standard Bordeaux mixture 4–6–50 was made and allowed to settle for about two hours. The supernatant fluid was then siphoned off and combined with 5 per cent sugar solution. Leafhoppers allowed to feed upon this solution survived, on an average, 14 days. This material was tested

[3]Crystallized copper sulphate used in computing dilutions.

for copper and gave a negative test where the reaction would show the presence of copper when equivalent to a 1–50,000 solution of crystalline copper sulphate. There is certainly nothing in this solution which is toxic to insects, and when Bordeaux mixture is properly made the copper is insoluble in the supernatant fluid.

THE TOXICITY OF COPPER TO LEAFHOPPERS WHEN THEY OBTAINED IT THROUGH PLANT TISSUES. In order to test the toxicity of copper when it was available to the insects only through the medium of plant sap, the roots of young bean plants were placed in solutions of copper sulphate of different strengths. The leafhoppers were placed on the plants immediately after their roots had been put in the solutions.

The most clear-cut and striking results were obtained with a 1–100 dilution of copper sulphate. Leafhoppers feeding upon plants whose roots were placed in this solution and at an average temperature of approximately 80° F. died within six hours' time; at this time the plant showed no visible signs of the effects of the copper. At lower temperatures 97 per cent of all leafhoppers on these plants died within 48 hours.

When feeding on plants whose roots were placed in a 1–200 solution, 90 per cent of the leafhoppers died in three days, at a 1–250 solution 100 per cent died in three days, at a 1–300 solution 96 per cent died in five days, a 1–500 solution gave 69 per cent mortality in five days, a 1–900 solution gave 75 per cent mortality in five days, and a 1–1,000 solution showed a 62 per cent mortality in five days. It is thus shown that marked toxicity occurred within from three to five days for all strengths, up to and including a 1 to 1,000 solution of copper sulphate.

Strengths of from 1–1,000 to 1–7,500 gave 80 and 40 per cent mortality, respectively, in approximately 10 days, whereas the plants in water used as untreated checks gave only 15 per cent mortality over a 10-day period.

ANALYSIS OF LEAVES FOR COPPER. Leaves were taken from the plants whose roots had been placed in copper sulphate solutions at 3-day intervals and tested for copper. This test was made by expressing the plant juice from the leaves and removing the proteins by precipitation. Copper was then precipitated in appreciable quantity from leaves taken from plants held in solutions up to and including the 1–5,000 dilution. Both the hydrogen sulphide and the potassium ferrocyanide methods were used with positive reactions.

This has no practical bearing upon spraying with Bordeaux mixture but these experiments have demonstrated conclusively that copper is

taken into the plant system and as such is toxic to the leafhoppers feeding upon the plant, and at the time of the insect's death, the copper can be detected in the plant juices by chemical analysis and precipitation.

Is Lime as Toxic as Copper Sulphate? Sprays of copper sulphate at different strengths were each applied to specific plants each day for seven consecutive days. After the seventh spray leafhopper nymphs were confined to these plants. About 50 per cent of the nymphs reached maturity but those that died showed typical symptoms of what has previously been termed "Bordeaux death." They dropped from the plants and were unable to regain their position or remain there if placed on the plant. In addition, they died in a partially molted condition.

Plants sprayed with calcium hydroxide at the rate of 6 pounds to 50 gallons of water showed no injury and leafhopper nymphs were not affected by the lime. Furthermore, nymphs which hatched from eggs that were in the tissues of these plants when they were sprayed grew to maturity upon the same plants without being affected.

Other copper sprays, such as ammonical copper carbonate, copper-fishoil soap, and Burgundy mixture have shown similar toxicity to leafhoppers except that the death rate was much smaller as compared with that from Bordeaux mixture. This was to be expected, since the copper content in these sprays is lower than that in Bordeaux mixture.

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President T. J. Headlee: Next is a paper by M. P. Jones.

THE ONION MAGGOT (*HYLEMYIA ANTIQUA*) IN OHIO, 1929

By M. P. Jones, *Columbus, Ohio*

Abstract

The maggots caused about a million dollar loss to onions in some Ohio marshes. Bordeaux oil emulsion and the proprietary oil emulsions, which were used, gave about 45 per cent increase in yield. It was necessary to devise sprayers suitable to the larger marshes. In general three types of sprayers were used: First, the Bolins, second, a Myers spray pump and 100 gallon tank mounted on a Ford chassis, and third, an outfit constructed by a farmer consisting of 50 gallon barrel, spray pump, pump jack and a small motor, mounted on a Ford chassis.

During the summer of 1928, farmers in Ohio marshes noticed that many of their onions were dying because of onion maggot injury. The growers began to seek help from both the Ohio Experiment Station and the extension Service of the Ohio State University. It was then too late to give any assistance that year and as a consequence the crop was reduced several thousand bushels. In fact, o thene of leading growers and shippers stated that there was a million dollar loss in Hardin County alone due to onion maggot. There is no doubt but what the maggots have been present in Ohio for a great many years, but for some reason or other they have never caused commercial loss until the last few years.

Nearly all onions in Ohio are grown for table use. Very few sets are grown and these are generally planted on the uplands where the maggot has not constituted a menace. The seed for the large onions is planted during April in muck soil, usually in rows 14 inches apart. The yellow varieties are more universally planted than the white.

Early in the spring of 1929 the writer held a meeting at McGuffey, which is the largest onion center in Ohio. At this meeting preliminary results, obtained by the Ohio Experiment Station together with the results of the work in Illinois by Flint and Compton and the work in New York by Glasgow and Cook, were discussed. The greater number of the farmers thought that spraying was out of the question, but a few decided to try it. Arrangements were made for demonstration plots in each of the Hardin County marshes, namely, Scioto and Hog Creek. Even though these were not carried on from the research standpoint, the data collected may be of interest to some research workers.

The flies came out in great swarms the week of May 27, but for some reason the maggot population did not build up in the green onions in the Scioto Marsh. The data from the Scioto Marsh plots was temporarily disregarded, because of the light infestation and the location of the plots with reference to the soil level. Unfortunately, the check plots were on the head lands and because of the wet season onions on the raised portions of the field were universally better.

It was noticed, however, that the spray killed very young weeds and retarded growth of the older ones, so that where spraying was done early weeding was not necessary for more than two months. Normally they must start weeding within a very few weeks after planting. Because of the apparent weed control, the cooperator at the Scioto Marsh expects to spray this year, which will also be good insurance against onion maggot injury. Other growers in the marsh,

who rigged up sprayers, expect to spray again even though some started spraying too late for favorable results last year.

In the Hog Creek Marsh the maggots caused more injury and the results obtained from the demonstration plots were quite different. The yield of the entire crop was greatly reduced, because of a heavy wind storm about a month before harvest, which broke the tops of the onions.

The results for last year showed little difference in the yield between oil alone and where oil was used in combination with Bordeaux. The boiled lubricating oil compared favorably with the proprietary oils.

At harvest time the demonstration showed, from counts made by Jay Sleesman and the writer, that each of the sprayed plots yielded higher than the checks and that the average of all sprayed plots was a 45 per cent increase over the average of the checks. The onions in 30 crates were counted to get the comparative size from sprayed and unsprayed plots. The crates were filled to weigh 61 pounds gross. The average number of onions in the crates from sprayed plots was 490 as compared to 406 in the crates from unsprayed plots. The difference could not be attributed to spray alone, because thinning due to maggots would increase the size of each onion.

The per cent of infestation at harvest time from a count of about 15,000 onions showed almost ⅓ as many of the sprayed onions were infested as the checks. The per cent was very low in either case.

One of the greatest developments in the Hardin County Marshes was that of sprayers to meet demands of the farmers. Three types in all were used. The small tractor sprayer of the Bolins type was used by some growers. These tractors were too small to carry sufficient material to spray rows a quarter or a half of a mile long even though the spray tank was increased to the maximum carrying capacity of the tractor. Many onions were seeded with seven row drills, hence a boom with seven nozzles was necessary. Two larger type sprayers were developed which met the requirements quite well. A model T Ford chassis with motor was used to convey the sprayer. Some alterations were necessary, however, to carry this through the muck soil. The rubber tires were removed and ¼ inch by 6 inch strap iron was bent around and bolted in place of the rubber tires. Additional wheels were attached to the outside of each rear wheel. The wood cylinder, 7½ inches in diameter by 10 inches long, was placed between the original and the extra wheel and both wheels were tied together with U bolts around the spokes. The extra bearing surface was to carry the additional weight of the spray materials.

1—Center foreground—7 rows unsprayed check
(absence of onions due to onion maggots)
Right and left background—sprayed with Bordeaux oil

2—A farmer constructed sprayer as described in the narrative

Thus far both sprayers were constructed the same, but in sprayer A (Plate 15) the drive shaft was cut off close to the transmission and a Chevrolet transmission inserted. This feature gave a wide variation of speeds and the outfit could be made to move very slowly. The driver's seat was shifted well to the left and a 50 gallon barrel equipped with barrel sprayer was placed to the right. A pump jack was installed to the rear of the spray barrel and this was driven by a small gasoline engine. (In this case the motor from a May Tag washer.)

Another feature which may be of interest was that this sprayer was equipped with cultivating tools, so that spraying and cultivating could be accomplished in one operation. The cultivation attachment consisted of a series of Planet Jr. wheel hoes fastened to a rigid bar. This bar was suspended from three sections of roller door carriage, thus making the steering of the cultivator, to which is attached the spray boom, a separate unit from the other part of the chassis. This whole unit can be raised and lowered much in the same way as the discs on a grain drill.

With this ingenious outfit the farmer and his two boys were able to cultivate and spray about 10 acres per day. The water was hauled to the field in a large tank. The oil in a drum, copper sulfate solution in one barrel and lime solution in another barrel were hauled to the field in the rear end of a truck. Each container was equipped with spigot making it very easy to draw the desired amount of any material. The total cost of sprayer A with all attachments, except May Tag Motor, was $261.80. This included Ford chassis and motor at $78, total blacksmith charges $101, cultivating tools $41.80 and spray pump, pump jack, boom and nozzles $41.

Sprayer number B used the model T Ford as in sprayer A, except that between the Ford transmission and the Chrevolet transmission a sprocket wheel was inserted from which power was derived to drive the spray pump. A Myers spray pump and a 100 gallon tank were placed just back of the driver's seat. A spray boom was attached to the rear of the chassis and one man walked behind to guide this spray on the row. No attempt was made to attach cultivators. Growers with the latter type of sprayer drove to a large gravity tank located by a well or drainage ditch to refill.

The total cost of sprayer B was $310. This includes Ford chassis and motor at $25, cost of overhauling chassis $60, and the spray tank, pump, nozzles and fittings at $225.

The Bordeaux oil combinations have given favorable results and with the progress in developments of spray equipment the growers feel that they can prevent maggot injury to the onions.

PRESIDENT T. J. HEADLEE: Now we have a paper by F. E. Whitehead.

THE PEA WEEVIL PROBLEM

By F. E. WHITEHEAD, *Stillwater, Okla.*

ABSTRACT

Although the pea weevil, *Mylabris pisorum*, is one of our oldest pests and one whose control has long been considered solved, the writer is unaware of any place it is being controlled. Our present controls are based on the assumption that the weevil in the seed is the important source of infestation. The writer has planted weevil infested peas under weevil tight cages and grown them to maturity without infestation occurring, which indicates that weevil planted in seed is not the source of infestation.

By overwintering weevil in protected places out of doors, he has brought as high as 87 per cent of them through the winter, thus showing that it is possible for a high percentage of weevil, escaping from the peas before being stored, may overwinter out of doors and therefore may be important as the source of infestation.

The pea weevil (*Mylabris pisorum*) is one of the oldest pests of our country as well as the worst insect pest of peas known. It was first recognized in this country by Peter Kalm (7) in 1748 when he was collecting for Linnaeus. At that time he recorded it as being so numerous in parts of Pennsylvania, New Jersey, and New York, that the growing of seed peas had been discontinued. From that day to this the pea weevil has continued to cause the growing of seed peas to be discontinued in many parts of the country. At present it appears that it is likely to bring about the same conditions in the "Palouse" country, a part of northern Idaho, and eastern Washington, where the speaker has spent the greater part of his time during the past five years. Literature on the subject brings out the fact that even though entomologists have insisted for years that its control is known and easily applied, it has not been effectually controlled at any time since it was first discovered more than one and three-quarters of a century ago. This would seem to indicate that our controls may be basically wrong or at least much more ineffectual than has been maintained. Nevertheless, they are, in all essential respects, the same today as those recommended by Harris (7) 88 years ago, which consisted of destroying the weevil in the seed.

Further evidence, that our controls may be wrong is seen in the fact that even though the pea weevil is one of our oldest pests, its life history has never been definitely determined or if determined has not been recorded. The length of time spent in the egg and adult stages has been recorded in several vicinities. Chittenden (3) has determined the length of the pupal stage at Washington, D. C. The only definite record I have been able to find in American literature as to the length of the larval stage is in Crosby and Leonard (4), wherein they state, "In Italy, the larvae reaches maturity in 40 days after hatching."

Therefore, we know the length of the egg stage in various places, the larval stage in Italy, the pupal stage in Washington, D. C., and the adult stage in still other places. With such a patched up knowledge of its biology, it surely would not seem surprising if errors were made in recommending its control. It is my belief that our universally recommended control of fumigating the seed is basically wrong in that it does not strike at the true source of infestation.

Such a statement of course needs defense. One of the observations made that first led to this belief was as follows: In an isolated valley north of Moscow, Idaho, only two farmers grew peas. Each year for the preceding three years each had had his seed fumigated by a reputable seed house, whose fumigations I believe to have been effective. But still their infestations were uniformly high. This is but one outstanding example of numerous similar cases.

In order to obtain further information on this point the following experiment was conducted: Weevil tight cages sufficiently large for growing peas to maturity were constructed. In these at the regular planting time, were planted peas 50 per cent, 25 per cent ,and 10 per cent of which contained living weevil. The peas were then grown to maturity with no weevil from the outside having access to them and resulted in mature peas 100 per cent free from infestation. This experiment was repeated the following year except that this time 100 peas containing living weevil were thrown on top of the ground in one of the cages at planting time and again resulted in no infestation in any cage.

The work of the speaker was such that he was unable to be present at the time the peas were planted and during the most of the growing season either year. He therefore feels that further work is necessary before stating that such results, would always be obtained. However, should other experiments give similar results, it will be very strong evidence, that weevil planted in seed, instead of being the important source of infestation is of no importance at all.

Other possible sources of infestation are weevil escaping in the spring from stored peas and those escaping from the peas before being stored and overwintering out of doors. The escape of weevil from stored peas, may be prevented by storage in weevil tight bins or bags or they may be killed by fumigation. But those overwintering out of doors, if important, constitute a great deal more complicated problem.

Most writers on the subject have assumed that with the possible exception of the south, few weevil ever successfully pass the winter out of doors. In the vicinity of Moscow, Idaho, numerous peas may be found each fall that have been deserted by the weevil and living weevil may be collected all winter. The most frequent places found being under bark and slivers of posts or trees.

Wire cages containing living weevil were placed in various types of cover in the fall, such as grass, under boards, leaves, rubbish, etc., and others in more open places. Those in the open places all died, but a large percentage of those in the more protected places were alive and vigorous the following April in spite of an unusually severe winter. In one cage placed in the rubbish at the base of a lilac bush and covered with leaves, 87 per cent of the weevil survived. Both weevil within and outside of peas were used and a much larger percentage of those outside peas, survived than of those within.

With these facts in view it seems entirely possible that the real source of infestation is entirely different from that which we have always considered it to be and may prove the almost universal failure of our controls to be due to wrong principles involved rather than to poor application.

In closing it is desired to recognize the fact that Fletcher, Gillette, Felt, Bethune, Back and others have recommended the early harvesting and fumigation of peas and the destruction of peas left in the field, or any other measures to prevent the escape of weevil in the fall. However, these have been recommended only as supplementary measures and no record is made of any experimental work being carried on to determine their effectiveness, which leaves the problem open for further investigation.

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PRESIDENT T. J. HEADLEE: The next paper is by H. H. Schwardt.

BORAX AS AN INSECTICIDE FOR PROTECTING SEED[1]

By H. H. SCHWARDT, *University of Arkansas*

ABSTRACT

Powdered borax applied to corn at the rate of ten ounces in a bushel has effectively controlled the rice weevil. The four-spotted bean weevil has been controlled by the application of twenty ounces of borax in a bushel of cowpeas.

One of the outstanding problems of southern agriculture is that of protecting stored seed from weevil attack. Corn and wheat suffer heavily from the combined attacks of the rice weevil[2] and the angoumois moth.[3] Cowpeas are often severely damaged by the four-spotted bean,[4] and cowpea[5] weevils.

The use of a poison or repellent dust to control pests of stored seeds has been suggested by Metcalf (5), and more recently by Mackie (3), and Zacher (6). Metcalf recommended the use of air-slaked lime for the protection of cowpeas. One part of lime to two parts of cowpeas was a fairly effective rate of application. Mackie found that copper carbonate, applied at the rate of two ounces a bushel, controlled the granary weevil in wheat. Zacher (6) reports that dusts based on copper carbonate and compounds of mercury and arsenic gave fair control of the granary weevil. Probably more important is his observation that such a cheap and non-poisonous dust as magnesium oxide is also effective. However, Zacher's data for this dust are limited to observations made on only a hundred individuals of the granary weevil.

Experiments made with both poisonous and non-poisonous dusts at the Arkansas Agricultural Experiment Station in 1928 showed the possibility of controlling weevils in stored grains by this method. Calcium arsenate, lead arsenate, and sodium fluoride were the poisonous dusts tested and all proved highly effective. For non-poisonous dusts,

[1]Research Paper No. 163, Journal Series, University of Arkansas.
[2]*Sitophilus oryza*. (L.)
[3]*Sitotroga cerealella*. Oliv.
[4]*Bruchus quadrimaculatus*. (Fab.)
[5]*B. chinensis*. L.

sodium carbonate and borax were used. Sodium carbonate was ineffective, but it at once became apparent that borax was very effective. In both the early experiments and those reported in this paper, borax gave almost a 100 per cent kill of weevils in every test made.

Corn treated with borax at the rate of ten ounces to a bushel was put up in ventilated quart cans and each can supplied with 25 adults of the rice weevil. Untreated cans of corn, supplied with the same number of weevils, were provided as checks. After periods varying from four to seven months, all cans were opened, live and dead weevils counted, and the condition of the grain noted. Numerical results are given in Table 1. In every case the check cans contained large numbers of live and dead weevils, and the grain was completely ruined. The treated samples, however, contained a small number of dead weevils, practically no live weevils, and the grain was in almost perfect condition. That reproduction did occur to a slight extent is shown by the fact that more than 25 dead weevils were found in each treated sample. Germination tests made on borax-treated corn have shown that the viability was not lessened.

TABLE 1. *Sitophilus oryza*. NUMBER OF WEEVILS FOUND IN TREATED AND UNTREATED CORN AFTER A FOUR-MONTHS EXPOSURE TO INFESTATION

Treated with Borax, 10 ozs. per Bushel			Untreated		
Live	Dead	Total	Live	Dead	Total
1	34	35	524	168	692
0	35	35	191	128	319
0	71	71	474	102	576
0	50	50	227	141	368
0	60	60	281	105	386
0	39	39	183	135	318
0	35	35	351	101	452
0	40	40	248	207	455
0	208	208	955	59	1014
0	60	60	606	51	657
1	151	152	589	43	632
2	190	192	1356	278	1634
0	81	81	1294	93	1387
1	230	231	1174	92	1266
0	79	79	1105	108	1213
5	1363	1368	9558	1811	11369

Only a few tests have been made on cowpeas, but the results are encouraging, and further tests are now in progress. Cowpeas were treated at the rate of 20 ounces of borax in a bushel of peas, and each can supplied with 25 adults of the four-spotted bean weevil. After three months, treated samples were practically uninjured, had not decreased in viability, and contained only small numbers of dead weevils. In the same length of time, check samples were reduced

13 per cent in weight, they contained large numbers of live weevils, and the germinating power of the seed was reduced from 85 to 55 per cent, due to weevil damage. Numerical data are presented in Table 2.

TABLE 2. *Bruchus quadrimaculatus*. NUMBER OF WEEVILS FOUND IN TREATED AND UNTREATED COWPEAS AFTER A THREE-MONTHS EXPOSURE TO INFESTATION

Treated with Borax, 20 ozs. per Bushel			Untreated		
Live	Dead	Total	Live	Dead	Total
2	48	50	1010	755	1765
1	55	56	762	682	1444
0	69	69	618	344	962
0	55	55	1007	610	1617
0	73	73	1078	561	1639
3	300	303	4475	2952	7427

The action of borax on these insects is not well understood at present. It has been observed that very little feeding takes place in treated corn, also that few or no eggs are deposited. Two hundred kernels of corn taken at random from several treated samples were found to contain only two eggs, and 14 feeding punctures. These samples had been exposed to weevils for five days. Two hundred kernels taken from untreated samples exposed to weevils for five days, contained 68 eggs, and 70 feeding punctures. Similar counts were made on lots of a thousand cowpeas which had been exposed to a heavy infestation of the four-spotted bean weevil for three months. On a thousand treated cowpeas, only 125 eggs were found. A thousand untreated cowpeas contained 4,868 eggs, and only two peas in the thousand were without eggs. The rice weevil is killed by borax in approximately eight days. It starves in about the same length of time. The fact that very few feeding punctures were found on treated corn suggests that borax either acts by contact, or is repellent to the extent that weevils starve rather than feed on treated grain. Both Mackie (3) and Zacher (7) believe the dusts which they used acted entirely by contact.

Borax is not poisonous to animals, but apparently is detrimental if fed for a period of time. Hanzlik, Talbot, and Gibson (1) fed borax to adult rats at the rate of 3.7 milligrams, per kilogram, per day. Over a period of time these rats lost 17 per cent of their original body weight. Borated food was distasteful to the rats, and was consumed in smaller daily amounts than normal food, which may account for the loss. These investigators conclude that continued use of borated food is detrimental. Mathews (4) states that ingestion of borax causes a reduction in the amount of oil secreted by skin glands, and thereby causes the hair to fall. Kahlenberg (2) found that borax was not absorbed through

human skin, although boric acid passed through the skin and was present in the urine within five minutes.

Borax-treated grain cannot be recommended as food for live stock until more is known about its physiological effect, or until an economical method of removing it is devised.

Planting borax-treated seed will not add a toxic amount of boron to the soil. Planting corn treated at the rate of ten ounces in a bushel adds less than two ounces of borax to each acre. This amount is negligible.

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PRESIDENT T. J. HEADLEE: The next paper is by W. P. Flint.

EFFECT ON INSECTS OF TREATING SEED CORN WITH CERTAIN FUNGICIDES[1]

By W. P. FLINT, *Urbana, Ill.*

ABSTRACT

During the past four years hundreds of farmers in the corn belt have been using certain fungicidal treatments for seed corn. Some of the companies making these fungicides have claimed that they would act as insecticides. The results of a series of tests extending over several years indicate that such is not the case.

During the past few years Federal and State Pathologists have discovered methods of controlling some of the diseases which infect seed corn by treating the seed at the time of planting with certain chemical dusts. It has been demonstrated by various experimental workers that the treatment of seed corn with the proper chemicals increases

[1]Contribution No. 1 from Natural History Survey Project 3. 1.

the yield. As a result of this experimental work, manufacturers have placed upon the market a number of commercial seed corn treatments.

Most of the manufacturers of these dusts have not claimed that their products have any effect as insecticides. Some of the manufacturer,s however, in advertising their products and also on the labels of the containers, have stated that the materials which they are putting out for seed corn treatment would control not only certain fungi which infect the corn kernels or are carried over from year to year in the soil, but that they would also control insects which attack corn in the ground shortly after planting. In some cases their claims have been extended to cover not only the seed corn in the ground, but also the young corn plant.

In order to find out the effect of these treatments as insecticides, a series of tests have been conducted in Illinois covering the period of four years. In all of these tests the materials were applied to the corn according to the directions given by the manufacturers and corn planted in fields at several points throughout the state. In making these tests fields were selected which included several different rotations, including corn after corn, corn after small grain, and corn on sod ground. When the corn was from six to eight inches high the hills were dug and carefully examined for the presence of insects.

The results of the tests which have extended over two years or more are shown in the following table. A study of this table shows at once that none of the materials tested show any marked insecticidal efficiency. There are indications that one or two of the materials may have an effect in slightly reducing the numbers of certain insects. This is true in the case of Semesan Jr. where tests on 532 hills of corn covering a four-year period have shown a rather consistent reduction in the number of corn field ants and corn root aphids. The number of wireworms in the hills treated with Semesan Jr. were somewhat greater than the average number found in the check and with other insects the infestation was approximately the same. It is obvious from a study of the table that none of the materials so far tested would be of sufficient value as insecticides to warrant the expense of using them as seed corn treatments to prevent insect injury.

TABLE 1. RESULTS OF TESTS WITH SEED CORN TREATMENTS AS INSECTICIDES

Treatment	No. Hills	Per cent Hills Infested by						
		Corn Field Ants	Corn Root Aphids	Corn Seed Maggots	White Grubs	Wireworms	Corn Seed Beetles	Thief Ants
Four years' tests:								
Uspulum	420	15.2	11.2	9.3	5.2	8.0	—	—
Semesan, Jr	532	10.1	6.0	3.0	1.3	8.3	1.5	.8
Three years' tests:								
Semesan	356	19.1	14.6	6.7	2.5	5.3	1.4	.6
Std. Oil H-1	332	15.0	10.0	10.0	4.5	4.0	4.5	3.6
Corona 620	316	22.8	19.9	3.1	4.4	6.0	.3	2.2
Bayer Dust	268	17.1	14.5	6.7	2.6	5.6	1.1	—
Field No. 54	381	6.8	6.5	—	.3	9.4	2.2	—
Plantaide	384	15.9	11.4	.3	1.8	8.0	1.0	.5
Two years' tests:								
Bayer Copper Dust	184	13.0	10.3	—	1.6	6.4	—	1.0
Semesan 13-U	340	26.1	18.5	.9	4.7	10.0	.9	.6
Corona 640-S	220	24.5	21.3	2.7	4.5	3.1	1.8	.4
Marley's Copper Dust	252	7.5	5.9	—	—	9.9	—	.8
Ceresan	256	16.0	8.9	.4	.8	8.9	—	1.2
Carbola	252	12.7	10.3	—	1.1	16.0	—	1.9
Merko	256	19.1	14.0	.4	—	4.0	—	1.6
Sterocide	256	19.1	11.7	—	1.1	10.1	.4	3.2
Checks	2754	15.0	9.5	3.5	2.7	5.0	3.6	2.7

Section of Apiculture

Meeting was opened at 9:40 A.M., January 1, 1930.

PART I. BUSINESS PROCEEDINGS

CHAIRMAN BENTLEY nominated the following committees:

Nomination Committee—J. E. Echart, Chairman, F. B. Paddock and E. C. Cotton.

Resolutions Committee—S. W. Bilsing, Chairman, Kenneth Hawkins and O. W. Park.

Resolutions read by Dr. Bilsing.

MR. PHILLIPS: Why should apiculture section make an expression regarding the Mediterranean fruit fly?

CHAIRMAN BENTLEY: This section should concur and support the action of the general association.

WHEREAS, The presence of the Mediterranean Fruit Fly in Florida creates a situation fraught with the gravest danger to the horticultural and agricultural industries of the Southern and Western States, and

WHEREAS, The presence of this pest, one of major importance, constitutes a threat to the prosperity of the areas affected and exposed, and unless eradicated, will also affect very materially the interests of the consuming public of the nation, and

WHEREAS, By reason of this situation, the problem is one of national rather than sectional import, and

WHEREAS, The program of eradication adopted by the Federal Government has been prosecuted vigorously and effectively, and

WHEREAS, Competent and able authorities, after intensive study, are convinced that eradication is not only possible, but is actually being accomplished, now, therefore,

BE IT RESOLVED, by the Section of Apiculture, American Association of Economic Entomologists in session at Des Moines, Iowa, this 1st day of January, 1930, that the program as adopted and announced by the Secretary of Agriculture, Honorable Arthur M. Hyde, should be supported by the public and the scientific workers of this country, and further, that the appropriation of adequate funds by Congress for the prosecution of this project is of paramount importance and should be made speedily available.

BE IT FURTHER RESOLVED, by the Section of Apiculture, American Association of Economic Entomologists in session at Des Moines, Iowa, this 1st day of January, 1930, that we do hereby endorse the efforts of the American Honey Institute to further the use of honey.

Moved by Mr. Park and seconded by Mr. Cotton that the resolutions be accepted. Carried.

Moved by Price and seconded by Bentley that the second resolution be adopted. Carried.

Nomination Committee made the following report:

R. L. Parker, S. W. Bilsing—Chairman

F. B. Paddock, E. N. Cory—Secretary

Vote taken by ballot and R. L. Parker was elected Chairman; F. B. Paddock, Secretary.

CHAIRMAN BENTLEY: I wish to thank you all on the program and am sorry that there is not a larger attendance, but the competition is rather keen this morning with the interesting papers being given in the other room. We are anxious that the incoming secretary lay quite a bit of stress on trying to build up a larger program next year. Officials should see if we cannot arrange for a little more time for our meetings next year. I thank you one and all for the help you have given me during the past year.

Motion moved and seconded to adjourn. 12:45 P.M.

G. M. BENTLEY, *Chairman*

F. B. PADDOCK, *Secretary*

PART II. PAPERS AND DISCUSSION

HISTORY AND ACTIVITIES OF THE SECTION IN APICULTURE

By CHAIRMAN, G. M. BENTLEY

As it seems to be the custom for a historical sketch of an organization after it has been functioning a few years, this fact has suggested itself as an appropriate subject for the Chairman's address this year.

It has now been 18 years since the Section of Apiculture came into being. The name of the section has changed once during this period. As with similar organizations, it has evolved from a very simple beginning to a section of no small importance. From a small gathering of six or eight interested in apiary inspection service and holding meeting at night or the noon hours, for there was no recognition of the section on the printed program of the American Association of Economic Entomologists, the section has had a wholesome annual growth.

Early in the history of the Section it was found to interest many entomologists, the topics discussed being of a wide importance, and as time went on the attendance at these special sessions increased. An attempt was made to hold an apiary inspectors' section similar to the one held for horticultural inspectors. Mr. A. F. Burgess, at that time Secretary of the Association of Economic Entomologists, was very receptive and did much to provide on the programs a brief space for

this growing section. A change in the Constitution of the American Association of Economic Entomologists had to be made and this accomplished; there had to be a Committee of Affiliation appointed to get the Section properly lined up with the Entomologists' Section. This arranged we would have the Section set some time on the regular programs.

The requests of the committees met with favor and this Section really had its birth in 1913 with Dr. Wilmon Newell, then at College Station, Texas, as President and Dr. E. F. Phillips, Apiculturist, U. S. Bureau of Entomology, Washington, D. C., as Secretary.

Meeting as an orphan gathering the year previous, B. N. Gates of Amherst, Massachusetts and Dr. E. F. Phillips were President and Secretary, respectively.

On the program in 1913 there were two papers presented, viz: "The Essentials of a Good Apiary Inspection Law" by Dr. Wilmon Newell, and, "Beekeeping and Apiary Inspections in Missouri" by Leonard Haseman.

The Section of Apiary Inspection in December 1914 held a night session with a more pretentious program with four presenting papers. These were:

Address of the Chairman—Wilmon Newell

"Distribution of American Foul Brood and European Foul Brood in the United States" by Dr. E. F. Phillips.

"A Simple Record System for Apiary Inspection" by W. E. Britton.

"Inspection as a Unit in the Massachusetts Apicultural Service" by Burton F. Gates.

At this meeting Dr. Wilmon Newell was Chairman and N. E. Shaw, Secretary.

Association of Apiary Inspectors of the United States and Canada

On December 30th, 1911, in Washington, D. C., there was formed a temporary organization of the above name with a view to increasing the efficiency of apiary inspection and to bring about a greater uniformity in the laws and more active cooperation between the various inspectors.

A committee on permanent organization was formed to report at a meeting to be held in Cleveland, Ohio, in December, 1912, in connection with the meeting of the Association of Economic Entomologists. Professor Wilmon Newell, College Station, Texas, was Chairman of this Committee.

A standing committee was also appointed on legislation for the purpose of drawing up a law incorporating the necessary and desirable features. The undersigned was appointed Chairman of this Committee.

All apiary inspectors and official entomologists of the United States and Canada who are interested in the advancement of apiculture are invited and urged to join in this movement for an increased efficiency in the fight against the brood diseases. For the present it was decided to levy an assessment, $1 per year, on each member

to pay necessary expenses. It is hoped that arrangements may later be perfected for affiliation with the Association of Economic Entomologists. Requests for membership and the assessment may be sent to the undersigned.

Respectfully,

Dr. BURTON N. GATES,
Amherst, Mass.,
Chairman.

E. F. PHILLIPS,
Bureau of Entomology,
Washington, D. C.,
Secretary.

Program, Wednesday, January 1, 1913. 1.30 p.m.

—Action on proposed amendment to the constitution.

Strike out the first sentence in Article II, Section 1. In the following sentence after the word "entomologists" add "horticultural or apiary inspectors," so that the sentence will read as follows: "All economic entomologists, horticultural, or apiary inspectors employed by the federal or state governments . . . may become members." In Article III, Section 1, omit the last sentence, which provides for the appointment of the membership committee by the President of the Association.

From: JOURNAL OF ECON. ENT., Vol. 6, No. 2, p. 19.

REPORT OF COMMITTEE ON AMENDMENTS TO THE CONSTITUTION

The following changes in the constitution have been proposed:

Strike out the first sentence in Article II, Section 1. In the following sentence after the word "entomologists" add "horticultural or apiary inspectors employed by the federal or state governments may become members. Making the Section read as follows:

Section 1. All economic entomologists, horticultural or apiary inspectors employed by the General or State Governments or by the State Experiment Stations, or by any agricultural or horticultural association, and all teachers of economic entomology in educational institutions and other persons engaged in practical work in economic entomology may become members.

* * * * * *

This committee approves these changes and recommends their adoption.

Respectfully submitted,
W. E. BRITTON, *Chairman*
WILMON NEWELL,
A. W. MORRILL,
Committee.

REPORT OF THE COMMITTEE ON AFFILIATION

JOURNAL OF ECON. ENT., Vol. 6, p. 20.

WHEREAS; a committee of this Association has conferred with similar committees of the American Association of Official Horticultural Inspectors and the American Association of Apiary Inspectors for the purpose of considering a plan whereby affiliation may be brought about with this Association, and,

WHEREAS; it is the opinion of the members of these committees that affiliation is desirable and will bring about better results and at less expense to the members than by maintaining separate and distinct organizations.

RESOLVED; That the plan outlined below be submitted to each Association concerned at its forthcoming annual meeting and that the same shall be put in force immediately if approved by the Associations concerned.

PLAN

In order to bring about affiliation, the American Association of Economic Entomologists agrees to amend its constitution to enable the present members of the American Association of Official Horticultural Inspectors and the American Association of Apiary Inspectors to become members and that said amendment will be made by striking out the first sentence of Article II, section 1 of the constitution, which reads as follows: "The membership shall be confined to workers in economic entomology," and in the following sentence after the words "entomologists" there shall be added words "or horticultural or apiary inspectors," so that the sentence will read, "All economic entomologists, horticultural or apiary inspectors employed by the Federal or State governments—may become members.

The members of the American Association of Official Horticultural Inspectors and American Association of Apiary Inspectors, who are not at present members of the American Association of Economic Entomologists, will, after making regular application for membership, be admitted on the same basis as other members.

After the affiliation has been accomplished, the annual meetings of the American Association of Economic Entomologists shall be arranged so that the Horticultural Inspectors may meet as the section of Horticultural Inspection, and the Apiary Inspectors may meet as the section of Apiary Inspection and the programs shall be made up so that as few papers as possible of mutual interest shall be presented at the same time before the American Association of Economic Entomologists and its sections.

The American Association of Economic Entomologists further agrees that one vice-president of its Association shall be a recognized Horticultural Inspector and he shall have general direction over and preside at, the meetings of the section of Horticultural Inspection and a similar arrangement shall be put in force for the section of Apiary Inspection. The secretary of the American Association of Economic Entomologists will have charge of the preparation and arrangements for the meetings, the general make-up of the program and the publication of the proceedings of the Association. Each section shall select its own secretary to keep a record of the proceedings and discussions at the sectional meetings and he shall prepare them for publication. It shall be the privilege of each section to bring any matters of special interest in its work to the attention of the American Association of Economic Entomologists for action by that Association.

The proceedings of the American Association of Economic Entomologists and sections, together with such papers as may be presented, shall be given equal privileges for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY.

T. B. SYMONS,
A. F. BURGESS,
T. J. HEADLEE,
Committee.

MR. E. P. FELT: It seems to me that we ought to act first on the report of the committee on amending the Constitution and I move that the report of this committee be adopted.

By vote of the Association the report was adopted.

PRESIDENT W. D. HUNTER: Is there any further discussion? If not, I will now put the motion to accept the report of this committee.

The motion was duly carried.

A report was read by Mr. Wilmon Newell in behalf of the Apiary Inspectors:

APIARY INSPECTORS COMMUNICATION

To the Association of Economic Entomologists: The Association of Official Apiary Inspectors of the United States and Canada, through the undersigned committee, request permission to affiliate with your Association as a "section" thereof, the chairman of such "section" to be a vice-president of your Association, and the proceedings of the "section" be published as are other proceedings of the Association of Economic Entomology.

WILMON NEWELL,
S. J. HUNTER,
T. J. HEADLEE,
Committee.

In view of the absence of Mr. Symons, chairman of the Committee on Affiliation, action on this request was postponed until the next session.

JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 6, No. 2, p. 6.

REPORT OF THE COMMITTEE ON THE CONSTITUTION

Considering that the Association now has two vice-presidents, one of which presides over the section of Horticultural Inspection and the other over the section of Apiary Inspection; that in the absence of the President there is no regular officer to preside over the general meeting if held at the same time as the section meetings; and that it is often impossible for all of the officers to be present,

Therefore, the committee recommends the adoption of the proposed amendment to the Constitution as published in the program providing for "one-vice-president and an additional vice-president for each section."

* * * * * *

W. E. BRITTON,
S. J. HUNTER,
FRANKLIN SHERMAN, JR.,
Committee.

REPORT OF COMMITTEE ON RELATIONSHIP OF SECTION AND BRANCHES TO THE CENTRAL ASSOCIATION

Your committee appointed to consider the relationship of sections and branches to the central organization respectfully submits the following:

We recommend that the official name of the Horticultural Inspectors be changed from American Association of Official Horticultural Inspectors to Section on Horticultural Inspection.

We recommend that the official name of the apiary inspectors be changed from Section on Apiary Inspection to Section on Apiculture, and that their activities be extended to include research in apiculture and education in apiculture.

As a guide in establishing any future sections and to record a definition of the activities of existing sections, we recommend that the purposes of sections be understood to be to discuss topics which are of such special nature as to be of only general interest to the majority of the members and of special interest to a limited number.

Respectfully submitted,
R. A. COOLEY,
J. G. SANDERS,
E. F. PHILLIPS,
Committee.

MR. R. A. COOLEY: In connection with this report, I would like to say in regard to the change in the name of the Section of Apiary Inspection that this is desired by that section so as to enable it to consider research and educational matters in connection with apiculture as well as inspection work. There is, of course, no membership in the sections other than membership in the central Association and any members of the Association are permitted to attend meetings of the sections and take part in their deliberations.

I am quite certain that this statement will clear up some uncertainty among our membership. Papers presented at the sections are printed in the JOURNAL, and it is of course understood that no action or policy can be taken by a section that would commit the Association without referring the matter to it for approval.

By vote of the Association the recommendations were adopted.

At the 1915 meeting held at 8:00 P.M. there were four papers presented, viz:

"The Function of the Apiary Inspection Section"—E. F. Phillips

"The Desirability of Inspection Work from the Standpoint of the Queen Breeder"—E. R. Root

"Outline of Apiary Inspection in Ontario"—Morley Pettit

"Suggestions for Efficiency and Economy in Apiary Inspection Service"—H. A. Surface.

This year Dr. E. F. Phillips of Washington, D. C., was our Chairman and N. E. Shaw, Columbus, Ohio, Secretary.

The Section of Apiary Inspection in 1916 held a night meeting with the presentation of seven papers. Dr. T. J. Headlee gave the address as Chairman. The other papers were:

"Some New and Practical Methods for the Control of European Foulbrood"—E. G. Carr

"The Way I would Like to Carry on Bee Disease Control"—Morley Pettit

"Problems of Bee Inspection"—Frank C. Pellett

"The Results of Apiary Inspection"—E. F. Phillips

"The Principles of a Course in Beekeeping"—B. N. Gates

"The Opportunity and Rewards in American Beekeeping"—E. R. Root.

Mr. N. E. Shaw, Columbus, Ohio, was Secretary of the Section.

This was our first program which included subjects other than apiary inspection.

In 1917 the Section changed its name from Section of Apiary Inspection to Section of Apiculture. The Chairman this year was B. N. Gates, Amherst, Massachusetts, and the Secretary, N. E. Shaw, Columbus, Ohio. At this meeting there were six papers given.

Address of Chairman—B. N. Gates

"Important Factors in the Spread and Control of American Foul Brood"—E. D. Ball

"Extension Methods in Apicultural Work"—G. C. Cale

"An Unusual Disease of the Honey Bee"—Elmer G. Carr

"Foul Brood Eradication Work in Texas"—F. B. Paddock

"Missouri Beekeeping"—Leonard Haseman.

In the previous sessions the brood diseases and various aspects of apiary inspection service have been emphasized. Research with few papers of general interest make up the following programs.

The session on December 26, 1918 was also a night meeting. Franklin Sherman, Jr., gave the address of Chairman, and in all this meeting carried on its program of nine papers as follows:

"Beekeeping Since the Declaration of War"—E. F. Phillips
"Developing Commercial Beekeeping in a Clover Region"—Morley Pettit
"Relative Importance of Management and Breeding of Bees"—E. L. Sechrist
"The Work of the Entomologist in Developing Bee Husbandry Within the Limits of his State"—T. J. Headlee
"The Present Outlook in Beekeeping"—E. R. Root
"The Relation of Beekeeping to Bee Behaviour"—Geo. S. Demuth
"Beekeeping Club and the Work of the Apiculturist in the Division of Extension"—Geo. S. Rea
"Boys and Girls Bee Clubs"—F. C. Pellett.

The Secretary for this year was G. M. Bentley.

The increased attendance and the keen interest by the entomologists was very stimulating and the prompt response to letters sent out indicated that the Section was supplying a real need.

Now that emphasis had been directed mainly along lines of inspection service, it was deemed wise to branch out into other important phases of Beekeeping. The experiment was tried with gratifying success and the program for 1919 carried 12 papers as follows:

"Some Phases of Beekeeping in Connecticut"—W. E. Britton
"The Economic Importance of Beekeeping in Entomological Work"—E. R. Root
"What Some Entomologists are Doing for Beekeeping"—Kenneth Hawkins
"Honey Production"—G. A. Koger
"Boys and Girls Bee Clubs"—F. C. Pellett
"Adaptation of System to Locality"—F. C. Pellett
"The Relation of Bees to Fire Blight"—H. A. Gossard
"Some Old New Phases of Bee Disease"—E. F. Phillips
"Preliminary Notes on the Value of Winter Protection of Bees"—J. H. Merrill
"Beekeeping in the California National Forests"—G. A. Coleman
"Sweet Clover as a Bee Pasturage"—G. G. Ainslie
"Arsenical Poisoning of Bees"—W. A. Price.

The 1920 meeting also had a night session which was also an outstanding success. F. B. Paddock was Chairman and G. M. Bentley, Secretary. The program was as follows:

"Better Queens"—F. B. Paddock
"Some Apicultural Investigations"—Wallace Park
"The Problem of Controlled Fertilization of Queen Bees"—L. V. France
"The Relationship Between the Complete Life Cycle of the Honey Bee and the

Blooming Dates of the More Important Honey Plants"—H. B. Parks
"Further Notes on the Value of Winter Protection of Bees"—J. H. Merrill
"Beekeeping Problems Which Should be Undertaken by the Experiment Stations"—F. C. Pellett
"Symposium"—"Foul Brood".

PROGRAMS OF SECTION OF APICULTURE

December 29, 1921—8:00 p. m.

"The Relation of Climate to Beekeeping Manipulation"—H. F. Wilson
"Essentials to Apiary Practice and Management"—Morley Pettit
"The Correlation Between the Physical Character of the Honey Bee and its Honey-Storing Ability"—J. H. Merrill
"Time and Labor Factor Involved in Gathering Pollen and Nectar"—Wallace Park
"Bees and Nectar Flows"—H. B. Parks
"Studies on the Temperature of the Individual Honey Bee"—G. B. Pirsch
"Cost of Poor Queens"—F. B. Paddock
"Factors Affecting the Success of American Foul Brood Campaign"—S. B. Fracker.
Officers for this meeting were: H. F. Wilson, Chairman; G. M. Bentley, Secretary.

December 28, 1922—8:00 p.m.

"Relation of the Texas Agricultural Experiment Station to Beekeeping in Texas"—M. C. Tanquary
"Utilization of Various Carbohydrates as Food for the Honey Bee"—E. F. Phillips
"A Two Year's Brood Curve for a Single Colony of Bees"—W. F. Nolan
"Investigation of the Queen"—F. B. Paddock
"Value of Winter Protection for Bees"—J. H. Merrill
"Rehabilitation Classes in Apiculture"—E. N. Cory
"Temperature Reaction of the Honey Bee to Her Cluster"—L. V. France
"Legislation to Protect American Beekeeper Against the Isle-of-Wight Disease"—Rea, Fracker, Gooderham
"Isle-of-Wight Disease with Special Reference to Geographical Distribution"—E. F. Phillips.
Officers were: M. C. Tanquary, Chairman; G. M. Bentley, Secretary.

While the interest and attendance of the night sessions of the Section of Apiculture were good and increasing each year, it was thought by many of those most interested in the good to be accomplished by the papers on Apiculture that a morning or afternoon session would make it possible for more to attend if the time could be arranged not to conflict with regular program of the Economic Entomologists. The arrangement was perfected. The results in number of papers and attendance were most gratifying. Fourteen appearing with papers as shown by the following program.

December 29, 1923—10:00 a.m.

Address by the Chairman—S. B. Fracker

"Methods of Teaching Beekeeping"—Symposium.

A. "Content of the Elementary Course"—J. S. Hine

B. "Laboratory Methods"—G. M. Bentley

C. "Methods of Handling a Winter Short Course"—H. F. Wilson

D. "Research Problems Adapted for Graduate Students"—F. B. Paddock

E. "Other Preparation Needed by Those Majoring in Beekeeping"—F. E. Millen

"The Honey Bee as an Agent in the Pollination of Apples, Pears and Cranberries"—Ray Hutson

"Seasonal Variation in Brood Population"—W. J. Nolan

"Notes on Fall Feeding"—F. B. Paddock

"Storing and Ripening of Honey by Honeybees"—Wallace Park

"Temperature Changes in the Hive During a Honey-flow"—J. I. Hambleton

"Spreading of Foulbrood by Un-intelligent Treatment"—E. R. Root

"The Relation of Bacillus Alvei to Confusing Symptoms in European Foulbrood"—A. P. Sturtevant

"The Status of Isle-of-Wight Disease in Various Countries"—E. F. Phillips.

The officers in 1923 were: S. B. Fracker, Chairman; G. M. Bentley, Secretary.

December 31, 1924—9:30 a.m.

"Foul Brood Diseases in Mississippi"—R. W. Harned

"The Seventh International Apicultural Congress"—E. F. Phillips

"Notes on Bee Diseases in Connecticut"—Philip Garman

"Some Things Entomologists Might Easily do to Promote Honey Production"—Kenneth Hawkins

"Physiological Factors Affecting the Development of the Brood Diseases of Bees"—A. P. Sturtevant

"Brood Rearing Studies"—J. H. Merrill

"The Quantitative and Qualitative Effect of Weather upon Colony Weight Changes"—J. I. Hambleton

"The Sense of Smell as a Factor Enabling the Bee to Locate Pastures"—W. A. Price

"Federal Cooperation in Apiary Inspection Proposed"—S. B. Fracker

"Brood-rearing Determination"—W. J. Nolan

"Inspection Methods in Different States"—Symposium.

Chairman, R. W. Harned—Secretary, G. M. Bentley.

December 30, 1925—9:30 a.m.

"Research in Apiculture"—R. L. Webster

"Investigation Directed to the Honey Market"—E. W. Atkins

"The California Buckeye and Its Relation to the Hive Bee"—G. H. Vansell

"Chronological Distribution of Bee Moth"—F. B. Paddock

"Experiments in Attracting Queen Bumblebees to Artificial Domiciles"—T. H. Frison

"Braula coeca"—Virgil Argo

"More Knowledge Needed Concerning the Diseases of Adult Bees"—C. P. Dadant

"The Use of Water-Soap-Formalin Solution for Disinfecting American Foul Brood Combs"—G. H. Vansell
"The Cornell Beekeeping Library"—E. F. Phillips
"Apiary Inspection in Pennsylvania"—Green and Hadley
"Nectar Carriers versus Water Carriers"—O. W. Park
"Symposium—Spraying and Dusting of Fruit Trees and their Effects upon the Honey Bee"—Leader, F. C. Pellett.
Chairman, R. L. Webster—Secretary, G. M. Bentley.

The meeting in 1926 was characterized by an afternoon and evening session, both well attended.

December 29, 1926—1:30 p.m.

"The Need of a National Beekeepers Organization"—J. I. Hambleton
"The Five Year Brood Record of a Single Queen"—W. J. Nolan
"Waxworm Fumigation Experiments"—F. B. Paddock
"Federal Honey Grading Rules"—E. L. Sechrist
"Studies on the Evaporation of Nectar"—O. W. Park
"Effectiveness of the Area Clean-up Method for American Foul Brood in Tennessee"—W. L. Walling
"The Present Status of Sterilization of American Foul Brood Combs"—A. P. Sturtevant
"The Fertilization and Hibernation of Queen Bumblebees under Controlled Conditions"—T. H. Frison
"Gaseous Chlorine as a Disinfectant for American Foulbrood"—Ray Hutson
"Certain Phases of Apicultural Research in the United States"—J. I. Hambleton

December 29, 1926—8:00 p.m.

"Some Things I Saw and Heard While Visiting Beekeepers and their Societies in Europe in Summer of 1926"—E. F. Phillips.
Chairman, J. I. Hambleton—Secretary, G. M. Bentley.

The 1927 meetings were held in afternoon and evening to avoid conflicts with important meetings.

December 28, 1927—9:30 a.m.

"Disinfecting Combs"—G. L. Jarvis
"Colony Population"—W. J. Nolan
"Crop Failure"—J. M. Robinson
"Marketing Honey"—G. E. Demuth
"The Pathogenic Effect of the Mite, *Acarapis woodi* Hirst, on the Thoracic Tissues of the Honeybee"—E. J. Anderson
"Symposium—Progress Reports in Apicultural Research"—Leader, J. I. Hambleton

December 27, 1927—3:00 p.m.

"Undergraduate Courses for Apiculture Specialists"—F. E. Millen
"The Cause of Fermentation or Souring of Honey"—G. E. Marvin

"Some Points in Handling Honeybee Packages, Both in Shipping and Installing Them"—Morley Pettit

"The Amoeba Disease of the Honeybee in the United States"—J. W. Bulger

"Area Clean-up of Foulbrood"—F. E. Millen

"New Diseases of Honeybees"—C. E. Burnside

Chairman, F. E. Millen—Secretary, G. M. Bentley.

December 29, 1928—9:30 a.m.

Address of the Chairman—H. F. Wilson

"The Presence of Wax-globules as a Cause of Cloudiness in Honey"—E. L. Sechrist

"The Effect of Color Classification on the Domestic and Foreign Market"—J. I. Hambleton

"The Yeasts of Honey and How they are Carried by the Honey Bee"—Wilson and Marvin

Preliminary Report on Formaldehyde Gas Treatment of American Foul Brood Combs"—C. E. Burnside

"The Respiratory Exchange of the Honey Bee"—G. H. Vansell

"Brood Rearing Cycle of Carniolan Bees"—W. J. Nolan

"Weather and its Influence on Changes in Hive Weight"—J. A. Munro

"The Effects of Moving Bees at Orchard Blooming time"—Ray Hutson

"Definition of a Commercial Beekeeping Region"—E. F. Phillips

"The Influence of Humidity upon the Sugar Concentration of the Nectar of Various Flowers"—O. W. Parks.

Chairman, H. F. Wilson—Secretary, E. N. Cory.

This brings our history and activities up to our present meeting here at Des Moines. The progress through the 18 years has been marked with success. The Section has had the effect of standardizing the apiary inspection service in the States; it has brought the beekeepers and inspection officials together; it has stimulated apicultural research and it has been the means of bringing much of this research to those especially interested in apiculture.

BEE HIVE TEMPERATURES

By GEO. H. VANSELL, *Davis, Calif.*

ABSTRACT

Partial summary of hive temperature observations from Davis, California. Special winter protection appears extremely valuable from the standpoint of pollenization but of little use in honey production locally.

The records from which these notes are taken were made at Davis, California, in part as a comparative check between bees in California, where winter protection is looked upon as impractical, and those under colder conditions, studied earlier by Phillips and Demuth, Gates,

Wilson and Milum, and Dunham. Winter hive temperatures were recorded for packed and unpacked colonies. Records were also made under summer conditions. Thermacouples and Bristol recording

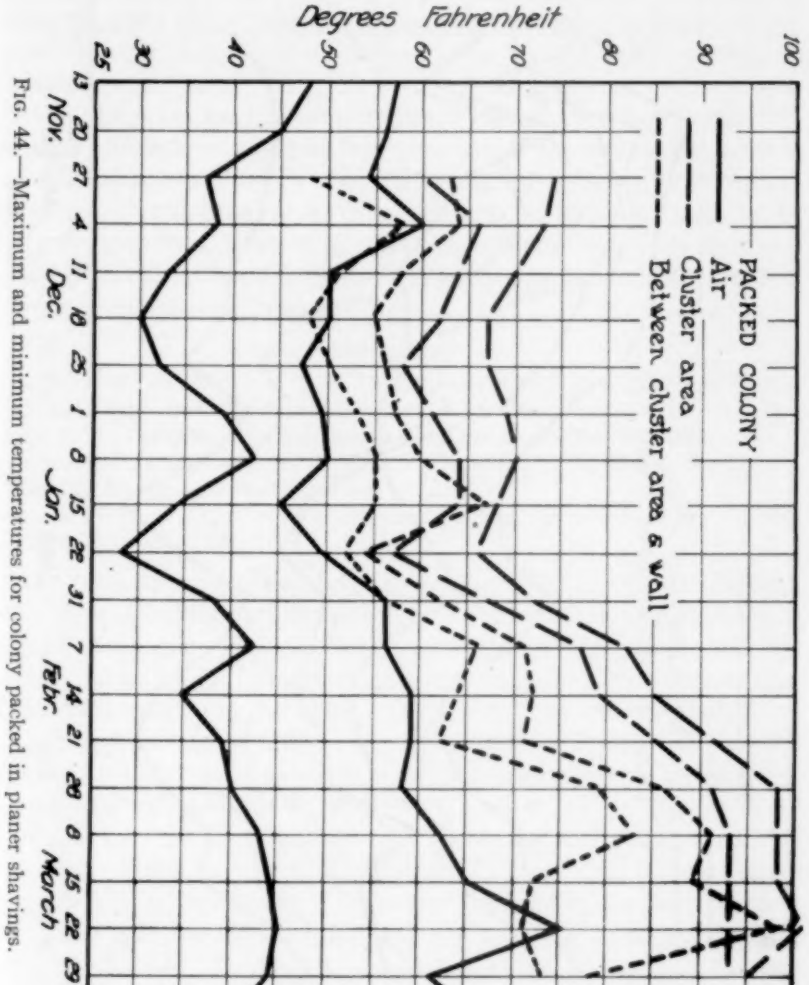

FIG. 44.—Maximum and minimum temperatures for colony packed in planer shavings.

thermometers were used. Attempts were made to ascertain the practical value of winter protection for both pollenization and honey production.

The usual brood nest temperature was near 95°F. although 100° was often reached in the packed colonies even as early as the middle of March. During the broodless period from November to January

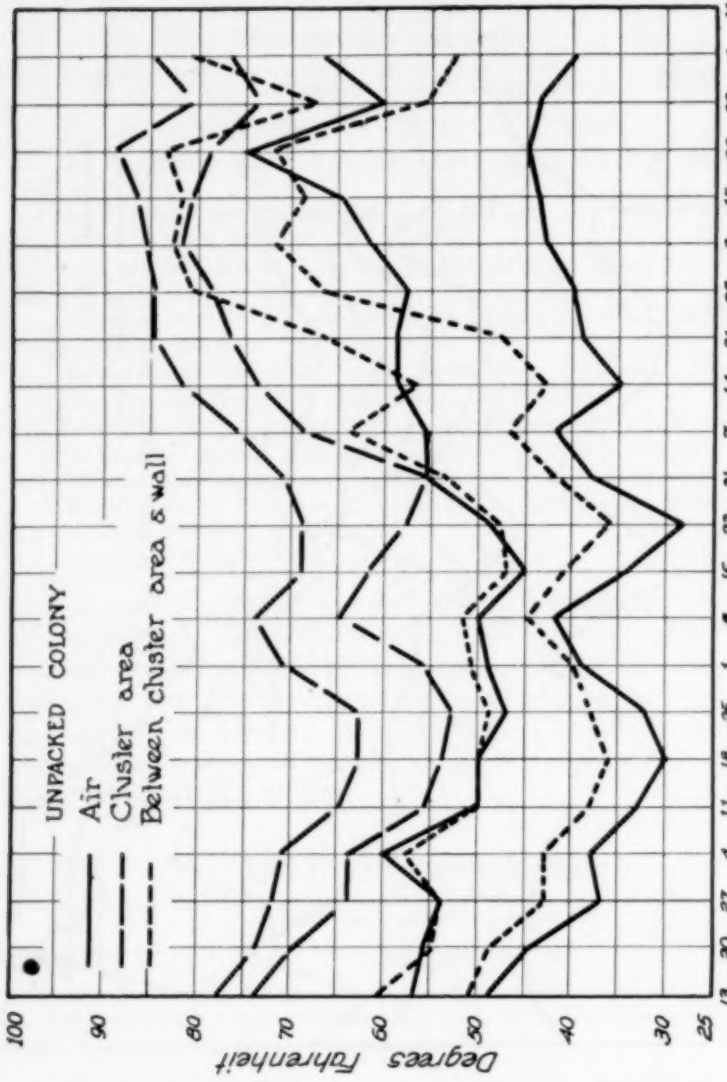

FIG. 45.—Maximum and Minimum temperatures for unpacked colony.

the minimum record was 51°F. for the bee cluster with no hive packing when outside temperature lowered to 26°. Between the cluster and the hive wall the minimum was 35°. In comparison, the cluster and

hive minima were 62° and 47° for colonies packed in planer-shavings. When the air temperature rose to 116°F. in summer, the brood nest of a colony in the sun reached 108°.

Figures 44 and 45 picture temperature conditions (maxima and minima) averaged into seven day periods for the time indicated. Effects within the hive of varying air temperatures are thus made visible. Little variation is noted in the packed colony, a desirable condition for wintering bees.

At this location, the bees wintered with special protection were nearly twice as efficient for pollenization purposes, if the counted number of individuals issuing is a safe index. The entire population of an unprotected colony was often required in the hive for brood warmth during chilly days of fruit blossoming time, while many bees were available for field work from those packed. No special increase in honey production by packed colonies was noted.

References

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GATES, B. N. Temperature of Bee Colony, U.S.D.A., Dept. Bull. 96. 1914.

WILSON, H. F., and MILUM, V. G. Winter Protection of the Honey Bee Colony. Wisc. Ag. Exp. Sta. Research Bulletin 75. 1927.

DUNHAM, W. E. Relation of Heat to Brood Rearing. Gleanings in Bee Culture. 57:359–362. June, 1929.

MR. PHILLIPS: Some years ago in southern California Mr. Demuth and I were out there and we looked into the honey flow in relation to strength of colonies and in the orange region, it very frequently happens that at the opening of orange fruit bloom there are from two to four frames of brood. The bees are totally unable to take advantage of the nectar secretion of the citrus in California. I said what a pity your colonies are not in good shape to gather next week. He laughed. "Those bees will build up on orange and gather me an average of 40 pounds of surplus, they can build up on orange and gather a surplus from sage. What more would you want?" Mr. D. said, "It will take 200 pounds of orange honey." Bees need packing in southern California. There is no part of the world where winter packing is more needed.

MR. FREEBORN: It should be remembered that this is a locality study and at Davis our only nectar flow in the early spring is from the flowers of the apricots, plums, almonds, and peaches. Mr. Vansell is sure they do not make surplus honey. It is extremely important that they have a strong colony on hand. They depend more on bees for pollination than for honey. Colonies are usually rented for such months.

THE BEE MOTHS

By F. B. PADDOCK, *Ames, Iowa*

ABSTRACT

These are very ancient pests of the apiary. Their systematic history is interesting. Now the distribution is quite general and of considerable economic importance. The life history and food habits are distinctive for the two species. Natural factors in control are lacking and artificial methods are ineffective.

The beemoths (*Galleria mellonella* Linn. and *Achoria grissella* Hub.) constitute one of the hazards of the honey producing industry. Their ravages have been recognized by beekeepers from early times. Their destruction while never disastrous is never the less constant and considerable. The moths are general in distribution, they seem to survive in almost any climate and are not menaced by predaceous enemies or parasites. Methods of artificial control seem to be wholly inadequate to cope with these pests, serving merely as a means of temporary check.

HISTORICAL. The very earliest records of beekeeping indicate the presence of the greater moth in the apiaries and the destruction caused by it. Virgil in his writings on agriculture refers to the moth but it is evident that there was confusion between the insect loss and that caused by disease. Insects at this time were referred to as Tiniae. The Roman writer on agriculture, Columella, at the beginning of the Christian era tells of the loss to beekeepers by moths, then called Papilio. It seems this term was applied at that time to the adult stage of all moths and butterflies. Pliny also wrote of the depredations of Papilio in the bee hives.

Samuel Purchas writing in 1657 reviews the early history of the greater moth and records some of the points of life history. Reaumur called attention to the destructive powers of the moth. He classified this moth as a false moth in contrast to the true moths, of which the clothes moth was used for example. He says the papilio of the wax moth is of the tribe *Phalaenae*, "who fly at night and burn themselves in the candle." He further makes a definite statement concerning the lesser, as follows: "There are two sorts of these caterpillars who devour wax but I shall speak only of the more common, the l[illegible]." Linneus in his tenth edition in 1758 placed the greater moth as *Phalaena mellonella* but he does not list the lesser. Four years later Modeer in discussing the diseases and pests of the apiary in Sweden refers to *Phalaena mellonella*, and in 1764 Blom also of Sweden calls the moth of bee hives *Tortrix cereana*. The greater moth was mentioned by economic writers throughout Europe but no distinction was made to indicate the presence of the lesser. Fabricius in 1793 lists also the lesser moth in his System

of Entomology and in 1818 Hubner established the present generic position. In his System, Fabricius set up the genus *Galleria* to contain *mellonella*.

It is interesting that these two species of early insects should have attracted so much attention from both economic and systematic workers. Both species were early recognized as destructive, both without close relatives and both finally placed in restricted genera for their special benefit. There was considerable confusion among the early workers for there is a rather long list of synonyms, the most part in regard to the species name. The genus *Galleria* stands today with only the single species of *mellonella* representing it and in the same family, closely related, is the genus *Achroia* with only the species *grisella*. Forbes places these and four other genera in the sub-family *Galleriinae* of the family *Pyralididae*.

DISTRIBUTION. It may be said that the greater moth has a world wide distribution for it seems to be generally present wherever bees are kept. A few restrictions have been noted in regard to altitude and perhaps climate in the British Isles. It is interesting to trace the modern spread of the greater moth as into South Africa, Australia and New Zealand where rather definite dates of introduction are established. The lesser moth has a reputed world wide distribution but such a statement may need modification in details, especially until more definite information has been secured. This is made difficult because the species are not always identified so that the presence of moths may indicate one or both species. It would seem from the evidence obtained thus far that the lesser does not exist in the restricted areas of altitude and if it is in the new territory the introduction is very recent. There is no reason to expect that any territory will remain free from the lesser moth.

LIFE HISTORY AND FOOD HABITS. This confusion in the identification of the two species by the layman is due to the close association of the two species. Outside of the fact that both species persist in connection with bee hives there is not much common in their food habits or life history. The greater moth seems to establish itself first in an area, gaining entrance to the hives of weak colonies and thriving in the unused portions of the brood nest. The eggs are laid on the comb, on the underside of the thicker edge of the cell rim. Thus it escapes detection by the bees. The larva is extremely small but can gain entrance to the comb by at least two methods; it may come out on the rim of the cell and burrow toward the center of the comb in the area

between the cell walls, or it may eat directly through the cell wall and then towards the midrib in the fashion of leaf miners working between the two surfaces of a leaf. During this period the larvae are safe from the attacks of bees. A web tunnel is constructed wherever the midrib is eaten which serves as necessary protection. This tunnel construction follows closely on the destruction of the midrib. The cell walls are not disturbed until the midrib is destroyed then the larvae work toward either surface of the comb. During this period silken webs serve as protection with the old tunnels available in case of extreme need.

The actual food of the greater worm is still not completely defined. The earliest writers considered that this pest actually consumed the honey after the period when it was realized that the worm did not cause the actual destruction of the bees. Purchase in 1657 says, "The moth with her mealiness somewhat offends the bees, but except the hive hath few bees, or be altogether empty, she doeth no great harm." Reamur in 1744 writes of "the caterpillars who devour wax." "In order to strengthen the galleries adds fragments of wax." Huish in 1817 says, "The food of the larva is not wax but pollen and other such as bee cocoons. Pure and clean wax is never attacked by the moth, it is not found on new combs but most often attacks refuse. It gnaws wax but does not eat it." The early observations were right on the whole. The greater moth does not seem to be able to exist on pure wax or foundation. There is a decided preference for the brood combs with extracting combs serving as a second choice. The larvae do not appear to consume pollen for in new and light brood combs the tunnels seem to avoid the cells of stored pollen. It seems quite probable that they do prefer all brood cells, perhaps for the refuse but such food is not essential. In an early infestation particles of wax may be found on the outside of the tunnels and in the refuse under the combs, but when the infestation becomes excessive all of the refuse is reworked for every particle of wax.

The lesser moth usually appears after the greater has been established in an area. It does not seem to wage any fight to become established in a hive, in fact it often does not appear in ruins until after the greater has completed its work. Under natural conditions it seldom attacks combs, acting more as a scavenger, existing from the refuse accumulated by the greater. It has been taken from combs that were covered with an extremely heavy mould and apparently the greater larvae had passed up such combs. After an infestation of greater moth has been conquered the work of the lesser is soon visible. A

healthy infestation of lesser was taken from a sample of slum gum obtained from a foundation factory. It would seem that such material would not contain much food and in fact it had not been infested by the greater over a period of five years. A frame of partly drawn queen cells was attacked by the lesser moth at the Laboratory. The destruction by the lesser is most noticeable in pure wax. It will attack blocks of pure wax stored for shipment to the foundation mills, and it will readily attack exposed foundation. It has been considered a pest of stored section honey for years. Here it consumes the caps, which are of purest beeswax, and the honey runs from the cells, causing "leaky honey." It is reported by Forbes to "feed on dried apples, raisins, crude sugar, and apparently also dried insects." Experiments are now in process to check this list of foods. Such a wide range of food would prove interesting and would complicate the control problem.

Economic Importance. The loss caused by bee moths has been considered a serious handicap to honey production since the earliest times. It has never been possible to establish an actual loss for so many beekeepers have little information on their operations. It is true that weak colonies are usually attacked and such colonies have no great value. But the wax or combs destroyed in such colonies is just as valuable as the combs of strong colonies and would produce as much if the beekeeper would manage better. In this sense it cannot be said that the bee moth is a scavenger. The probable relationship of bee moth activities to the spread of disease among bees is being studied and it is hoped results will be available in the near future. The loss of combs in weak colonies must be a big factor and the loss of stored combs, either brood or extracting is much more than is appreciated by the producers. The destructive power of the greater moth is enormous, six or eight larvae will render a comb unfit for colony use, either for brood chamber or super. These pests remain ever present and a constant handicap to production.

Control. The natural factors of control have been ineffective with the bee moths. Climate, in the large sense, seems to have been a restricting factor. Altitude is considered the reason why areas of Austria, Hungary, Sweden and the Rocky Mountain region of the United States are free from this pest. There is evidently some factor of climate, perhaps excessive dampness, which holds the pests in check throughout Great Britain. These factors have served as natural checks with a few other pests in areas over the world.

It is especially interesting to have a pest of such antiquity as the beemoths, so free from predaceous enemies and parasites. Literature

records no enemies of any stage of either species of beemoth. One correspondent has recently indicated that the common field cricket probably fed on the larvae of the greater moth. Spiders have been reported as feeding on the greater larvae. If both of these enemies were actually operating it must be on a restricted basis and they certainly do not serve as an economic factor of control. Ten species of parasites have been reported on the greater moth larvae, the only stage of either species to be attacked. The parasites occur evenly distributed in three families and with one exception are primary parasites. However, these parasites are common on other species of economic pests, with one exception. Only three species of the recorded parasites are known to occur in the United States, at widely distributed areas and never have become established at any point.

Fumigation has been used as a means of combating beemoths for over 200 years. During that period practically every common material has been tested for its effectiveness in killing all stages of pests. These materials have met with varying success, depending on the environment. The problem of fumigation is associated with stored combs, both brood and extracting, and stored section honey. This means that the major part of fumigation is given during times of the year when only moderate temperatures prevail. One fumigation is given during the fall and another during the spring, with very little work during the summer and none during the winter.

Experiments have been conducted recently to determine the effectiveness of some of the newer materials and to check further on some of the older materials. The results of these trials covering a period of two years indicate some of the difficulties which are involved in the fumigation of combs in stacks of bodies or of supers. Temperature is a factor of prime importance for all fumigants lose their effectiveness at temperatures usually prevailing at time of customary treatment. Para was not effective below 75°, carbon bisulfide is only partially effective at 71° and calcium cyanide was not fatal at 70°. With a stack of even six Langstroth hive bodies a relatively high, slender container is given for fumigation. Many of the gases are heavier than air, so fall rapidly to the bottom of the enclosure, usually remaining there until dissipated. Therefore a killing concentration is not effected in the upper bodies of the stack. When bodies are piled in the ordinary manner there is considerable leakage at each joint which totals a relatively high per cent of loss of fumes during the dissipation of the material so that it is difficult to attain a lethal concentration under practical conditions.

There are then three factors, often working together, any one of which could account for unsatisfactory results in moth fumigation. In view of these considerations it will be necessary to rearrange the program for comb fumigation. The work should be planned effectively early in the fall and with temperatures much below 90°F, it will be necessary to increase the dosage of materials used. If an effective kill is obtained in the fall combs should be safe until spring when reasonable temperatures again prevail. It may be necessary to use lower stacks of combs for fumigation and extreme care must be used to have the stack more confining to gas, even if it is necessary to cover the joints.

Repellents offer a valuable aid in protecting combs from moths. Para is especially effective during the portion of the year when low temperatures prevail. It is a practice in Russia to dip combs in a strong salt solution before storage. These combs are soaked in water in the summer before using. This custom is considered practical over there but probably would not appeal to the producers of the United States. Experiments are under way now to determine the effectiveness of this practice as repellent to the bee moths.

More effective measures of artificial control are necessary to reduce the ravages of these insects. The factor of strong colonies in the yard is less effective so long as the insects can persist in liberal numbers in stored combs. It is in this part of the campaign that more definite results must be obtained and it is in this part that all factors can be controlled by the producer.

MR. MARVIN: I want to stress the effect of dampness. That seems to show some effect in Wisconsin as the moth is scarce around Milwaukee.

MR. PHILLIPS: I have been interested in wax moths for a long time, but have never done any work with them. They are not one of our outstanding pests, as Professor Paddock will agree. They are not in the same class with our disease problem. Wax moths being abundant offer opportunity for physiological work and I am glad to know he is working along that line. Some experiments have been made along this line in the U. S. Bureau. Wax moth larvae put in petri dishes in bee hive and the larvae put on cells of pollen grew until ready to burst. These things looked like pigs just before butchering. If they were put on comb foundation or on pure beeswax no growth occurred however. They kept nibbling away, but kept getting smaller instead larger. Some of us have seen the exhibits at meetings of another species of insect which in the absence of food keeps getting smaller and moults in order to become smaller.

MR. MILUM: The same applies to carpet beetles, which may be kept in bottles for several months without food and grow smaller and smaller. There are 13 moults in clothes moths. They gradually get smaller and smaller.

STUDIES OF METHODS USED TO DETECT HEATED HONEYS

By G. H. VANSELL, *Associate in Entomology, and* S. B. FREEBORN, *Associate Professor of Entomology, Univ. of Calif., Davis, Calif.*

ABSTRACT

1. "Overheated" honeys have been detected by the absence of active diastase and the Fiehe test which measures the amount of hydroxymethyl-furfural.

2. Diastatic activity is apparently dependent on the amount of pollen present in the honey and the absence of pollen may be the cause of condemning some honeys as overheated, such as navel orange and alfalfa.

3. Heat produces a furfural reaction in honey but the same reaction may be produced without heat by 30 minutes contact with concentrated HCl.

4. Storage or possibly crystallization play important roles in producing positive furfural reactions, particularly in extracted honeys, if sufficient time is allowed.

5. The Fiehe reaction is not a reliable test for overheating nor is the diastatic activity, unless the pollen count is taken into consideration.

The application of heat to extracted honey produces chemical changes that progress as the heat or length of exposure is increased from an undetectable state to the point where the honey is caramelized and decidedly undesirable. Theoretically, therefore, any honey that has been exposed to more heat than it would normally experience in the comb is a changed product and becomes something other than natural honey. This attitude has been adopted by one European country with the result that many shipments of American honey have been condemned as "overheated."

The methods used to detect heated honeys have been based on two known facts. First, heating destroys the diastatic activity, and second, heating of levulose produces furfural derivatives. Consequently, if active diastase is absent and furfural derivatives are present in small amounts (larger amounts suggest adulteration with commercial invert sugar), the honey may be declared to be overheated and cannot be marketed as table honey.

DIASTASE REACTION. Numerous methods based on the reduction of soluble starch solution by the enzymatic content of the honey have been utilized for the measurement of the diastatic activity. In some of these, the amount of honey necessary to reduce a given amount of starch in a unit of time has been used while others have utilized

the time required for a given amount of honey to reduce a given amount of starch at a stated temperature. The official German test is made by merely adding honey to starch solution and passing or rejecting the honey tested on the basis of whether the starch was reduced or present at the end of an hour's exposure at 37°C. Later refinements have been the rapid alcoholic extraction of the enzyme from the honey and the standardization of this washed extract to pH 4.4 in order to avoid contamination from the honey and insure a satisfactory working medium for the diastase. Considerable doubt has been thrown on the value of the diastase reaction by Vansell and Freeborn,[1] who have shown that the diastatic content of honey is caused by its contamination with pollen and is not a product of the bee's metabolism. They have also shown that normal comb honeys, for instance navel orange and alfalfa may be so lacking in pollen that the honey when tested is deficient in diastase and hence would be condemned as "overheated." California exporters familiar with this work have limited their examinations to the Fiehe test, an examination for the presence of hydroxymethylfurfural.

FIEHE TEST. When the levulose in honey is heated in the presence of an acid, a slight amount of hydroxymethylfurfural is produced. The presence of this material is then used as an indication of heating and the honey showing a positive reaction is condemned as overheated. Again in this test many modifications have been introduced. The test now in use in Germany was kindly supplied us through the courtesy of Mr. Leslie E. Reed of the American Consulate at Bremen, and is as follows:

Five grams of honey are ground and dissolved in a mortar with pure ether which has been stored over metallic sodium. The ether extract is then poured into a small porcelain dish. After the evaporation of the ether at ordinary temperature, the residue is moistened with a newly prepared solution (or with one which has been stored in a place without light) of one gram of resorcin in 100 grams of *hydrochloric acid* of a specific gravity of 1.19. A strong cherry-red color lasting *at least one hour*, indicates the presence of artificial invert-sugar, whereas a weak, quickly disappearing orange-to-pink coloring might be the result of overheating.

This test is designed primarily for the detection of commercial invert sugar as an adulterant of honey, but a slight reaction not pronounced enough to indicate adulteration is considered to indicate

[1]Vansell, G. H. and Freeborn, S. B.—Preliminary Report on The Investigations of the Source of Diastase in Honey. JOUR. ECON. ENTOM. *22*:922–926. 1929.

heating. Lampitt, Hughes, and Rooke[2] have carried on the most extensive work yet published on the factors effecting this reaction and fail to find a single honey that showed a positive Fiehe reaction until enough heat had been applied to materially change the color of the honey and caramelize it to the extent that its flavor was decidedly affected. In this paper they point out the fallacies of the original technique of the Fiehe reaction together with those of its various modifications. Our observations check with those of the authors just mentioned whenever we used freshly extracted honey. However, with extracted honeys from one to three years old that had been allowed to crystallize, a positive Fiehe test (German method) was obtained in every instance before any heat was applied. Whether this idiosyncrasy was a result of storage alone or of crystallization it is difficult to say and a check on these findings rests with subsequent tests of extracted honeys, that are now negative at a later date after they have crystallized.

Crystallization is a purely physical phenomenon and it is difficult to believe that this process alone could be responsible for the change in reaction. However, it must be borne in mind that when a honey crystallizes, the levulose concentration of the material *in solution* increases from approximately 40 to more than 60 per cent, and it is assumed that the acid content of the solution also increases. This is caused, of course, by the elimination of the dextrose from solution. Given this greater concentration, the process of furfural formation may be accelerated. The absence of heat may have been compensated by the length of time required to produce the furfural in our samples. Heat merely accelerates the chemical reaction that proceeds slowly but just as surely in its absence.

In this connection it is worth pointing out also that differences in time required to complete the reaction may be somewhat dependent on the ratio of levulose to dextrose. It would be expected that a honey high in levulose might show a positive Fiehe reaction before one low in levulose in spite of the fact that neither had crystallized. In addition, the amount of acid present which acts as a catalyst in producing furfural derivatives, influences the reaction. We were able by adding one drop of concentrated hydrochloric acid to a 5 gram sample of alfalfa comb honey that was normally negative to the Fiehe test to produce after 30 minutes a positive Fiehe reaction. This was repeated several times with different honeys with the same result. It should be noted that no heat was required in these instances.

[2]Lampitt, L. H., Hughes, M. B., and Rooke, H. S.—Furfural and Diastase in Heated Honey. The Analyst, *54*:381-395. 1929

If, therefore, a positive Fiehe reaction can be produced in a normally negative honey in 30 minutes by the addition of a drop of concentrated hydrochloric acid without the intervention of heat, is it not feasible that the same reaction may proceed in nature with a weaker acid if sufficient time is allowed, particularly if the acid and the levulose, the chief source of the furfural derivatives, are concentrated by dextrose crystallization.

It would appear from the foregoing that except for freshly extracted honey that the Fiehe reaction is a faulty test for heating. The test for diastatic activity also fails to be trustworthy unless a pollen count is made of the sample. All pollens vary in their content of diastase but in our trials a count of at least 3000 pollen grains per gram was found to be the absolute minimum sufficient to produce enough diastase to enable the sample to reduce the required amount of soluble starch. A negative diastatic reaction and a pollen count in excess of 3000 grains per gram is trustworthy evidence of overheating.

PHILLIPS: I have been tremendously interested in California experiments, on diastase, because it tends to make me feel a little more comfortable about my own findings. Two other investigators have reported that diastase is normal in the alimentary canal.

In attempting to determine the carbohydrates in honey bees including soluble stages it was found in the work at the Bureau that there was no prolongation of life and no modification of starch. The iodine test was used and these were checked by means of testing the enzymes with the same result. It is further unfortunate that the Germans have applied tests to imported honey, which are not universally applied in their domestic honey. Heat is applied in Germany as well as here before bottling. We would have no right to complain of a requirement in imported honey in their country if they applied the same requirement to ours.

FURTHER OBSERVATIONS ON THE DETERIORATION AND SPOILAGE OF HONEY IN STORAGE

By GEORGE E. MARVIN, *Madison, Wis.*

ABSTRACT

Honey deteriorates after being extracted from the combs and the time of extracting and conditions under which honey is stored affect the rate of change. Fermentation, caused by sugar tolerant yeasts, is one cause of deterioration. When honey granulates, conditions are brought about which are conducive to the growth of these organisms. Carbon dioxide, rarely over 5% alcohol and a non-volatile acid are the byproducts of fermentation which cause the off flavor to fermented honeys.

Honey, which is to be sold in small containers, should be heated to 160°F., pailed and sealed while hot to prevent fermentation. The honey should then be cooled down suddenly for if held at high temperatures for some time, it will become slightly darkened. Honey in storage which has never been heated should be kept at temperatures below 52° F. to prevent fermentation and color changes.

Introduction

Contrary to a general belief that honey will continue for long periods without deterioriation, we have found at the Bee Culture Laboratory of the University of Wisconsin that honey deteriorates rapidly after being extracted from the combs and that the time of extracting and conditions under which it is stored, affect the rate of change.

It has long been considered best to keep honey at warm temperatures, but we believe, from the results of our investigation, that extracted honey should be stored at low temperatures to prevent color changes and to prevent fermentation while the honey is in storage. Honey darkens with age and the higher the temperature, the more rapid the color change.

In commerce these color changes are slow and seldom serious unless for some reason it is necessary to hold shipments for more than two seasons. However, another factor enters into the problem of honey storage and that is fermentation which frequently causes much loss on the part of beekeepers and bottlers in all parts of the United States and Canada.

It is now a well known fact[1] that honey fermentation is caused by yeasts, capable of developing in high concentrations of sugar as are found in honey.

When fermentation occurred, it was formerly considered that the honey had been extracted before being thoroughly ripened by the bees. In our studies we have found that yeasts are present in most natural honeys and when granulation occurs, conditions are made favorable for their multiplication.

Source of Yeasts. The starting point of our original experiment was with four samples of fermenting honey, all coming from Wisconsin. The honeys were put in class containers for observation. All of the samples had a soft granulation. Soon they became plainly divided into a lower granulated layer and an upper fluid layer with the surface covered with foam.

The odor reminded one somewhat of the bouquet of a sweet wine or fermenting canned fruit. Under the microscope one could observe

[1]See Bibliography.

yeast cells. As fermentation progressed, the fluid layer became greater and the granulated layer retreated.

Samples of these honeys were plated and yeasts grew in large numbers. (4) Five seemingly different types of colonies were taken from the plates, transferred to slopes and so the starting cultures for the experiment were secured.

Since the beginning of our honey fermentation work, we have received and have worked over samples of honey from California, Florida, Ontario, Quebec, Ohio, Kentucky, Maine, Illinois, Utah, Connecticut, Colorado, Hawaiian Islands, Porto Rico and Norway. We have isolated over 50 pure cultures of yeasts. There is still a tremendous amount of work to be done in classifying these yeasts.

EXPERIMENTAL. The yeasts used in this work were obtained by plating fermenting honey on honey yeast-water agar and from isolated colonies, transfers were made to fresh honey yeast-water agar slopes.

Yeast water was used to dilute the honey in the fermentations and the diagnostic sugars were dissolved in it. It was prepared by suspending starch free yeast in ten times its weight of water, steaming for two hours and sterilizing at 15 pounds pressure for two hours.

Diagnostic sugars were prepared by dissolving approximately two grams of the various sugars in 100 cc of yeast water. Ten cc were put in test tubes which were plugged and sterilized and on cooling were inoculated with the various honey yeasts. Care was taken in sterilizing the sugar media in order to avoid any decomposition of the sugars. The sugar present in a solution after fermentation was determined by the Shaffer-Hartman method as modified by Stiles, Peterson and Fred (7).

Alcohol determination: 100 cc of the honey medium after fermentation was completed were put into a distilling flask, a small amount of dry phenophthalein and brought to neutrality. 50 cc of distilled water was added, 5 grams of Na Cl and a little Tannic acid. 100 cc of distillate was caught, cooled to 15½ degrees C. and the specific gravity determined by the Picnometer and Westphal Balance.

Titrable acids: 50 cc of distilled water was added to 10 cc of the honey medium after fermentation and brought to boiling. Phenophthalein was used as an indicator and titration continued until the first permanent pinkness appeared.

Volatile acids: to 200 cc of the honey medium after fermentation, 5 cc N/5 H_2SO_4 was added. 1000 cc was steam distilled over. The distillate was brought to boiling, phenophthalein added and titrated with N/10 Na OH.

Non-volatile acids: 100 cc of honey medium after fermentation, was extracted for four days with ether. The extraction was titrated with N/10 Barium Hydroxide.

The amount of carbon dioxide given off by each yeast during fermentation was obtained by weighing a flask of fermenting honey at intervals. The flask was sealed with a fermentation trap, the carbon dioxide escaping through H_2SO_4.

Fermenting of Sugars by Honey Yeasts. A series of test tubes was set up, each tube containing 10 cc of approximately 2 per cent dextrose, levulose, sucrose, mannose, lactose, galactose and maltose in yeast water. The five cultures of honey yeasts were used. After 168 hours of incubation at 28 degrees C., the cultures and controls were analyzed for sugar.

Table 1. Fermentation of Various Sugars

(The figures after the cultures represent the grams of sugar fermented)

Sugar in Uninoculated	Dextrose	Levulose	Sucrose	Mannose	Lactose	Galactose	Maltose
Control	1.8	1.74	1.84	2.08	1.75	1.93	1.74
Culture 1....	1.76	1.67	.50	2.00	.10	.67	.77
Culture 1A...	1.75	1.67	.74	1.94	.08	.62	.52
Culture A....	1.75	1.66	.85	1.98	.08	.55	.97
Culture B....	1.77	1.66	.69	2.00	.07	.56	1.05
Culture C....	1.74	1.64	1.66	1.94	.07	.64	1.23

From the table one sees that the five honey yeasts are divided into three groups as to their ability to ferment sugars.

Group 1—Cultures 1, 1A and A. Dextrose, levulose and mannose are fermented energetically while sucrose, galactose and maltose are fermented more weakly.

Group 2—Culture B. Dextrose, levulose, mannose and maltose are fermented energetically while sucrose and galactose are fermented more weakly.

Group 3—Culture C. Dextrose, levulose, sucrose, mannose and maltose are fermented energetically while galactose is fermented more weakly.

With the Shaffer-Hartman method of sugar analysis it was impossible to find the exact amount of raffinose, melezitose, starch and dextrins that were fermented, so the following procedure was used to determine the fermentability of these substances by honey yeasts.

Ten cc of a 2 per cent solution of raffinose, melezitose, starch and dextrin made up in yeast water together with plain yeast water as a check were put in tall test tubes, plugged, sterilized, cooled and inoculated with the honey yeasts. A plug of sterile liquid vaseline

was put on the surface of the liquid, which hardened on cooling. With fermentable sugars, as the gas is evolved, the vaseline plug is pushed upward. By observing the height to which the plug is pushed, one can determine in a relative way the ease with which a sugar can be utilized by the yeast in question. With the honey yeasts, no gas was produced with raffinose, melezitose, starch or dextrin, so these materials are not fermented by the honey yeasts.

TABLE 2. RATE OF FERMENTATION PER 100 CC 50% HONEY WEIGHT OF CARBON DIOXIDE IN GRAMS GIVEN OFF

Culture	Days								Total Loss
	1	3	6	10	13	20	27	40	
1	—	.7	.9	.7	.7	1.1	.7	—	4.8
1A	—	.7	.7	1.3	.4	1.1	.7	.7	5.6
A	—	.7	.9	.4	.7	.9	.7	.2	4.5
B	—	.4	.7	.4	.7	.9	.7	.2	4.0
C	—	.7	.7	.7	.7	1.1	1.1	.2	5.2

Fermentation in a 50 per cent honey medium is relatively rapid compared with what it would be in an ordinary sample of honey. In the case of the latter, it requires a long time for the action to get started and it extends over a period of six months to a year. Evolution of carbon dioxide is very slow. In the 50 per cent honey medium the fermentation appeared to be over after 40 days and clearing was noticed.

The five cultures of yeast can be separated into three groups relative to ring formation in a flask of fermenting 50 per cent honey medium.

Culture A—forms a very light ring.

Cultures 1, 1A and B—form a medium heavy ring.

Culture C—forms a very heavy ring.

None of the cultures form a scum on 50 per cent honey medium, but a thick foam is usually present on the surface of the fermenting liquid when the action is at its height.

PRODUCTS OF FERMENTATION. During honey fermentation the products given off by the yeasts are carbon dioxide, alcohol and acid. Most of the acid given off is of the non-volatile type.

TABLE 3. FERMENTATION PRODUCTS FORMED PER 100 CC OF 50% HONEY

Culture	Carbon Dioxide Grams	Alcohol Grams	Tit. Acid cc N/10NaOH	Non-volatile Acids cc N/10 $Ba(OH)_2$	Volatile Acids cc N/10NaOH
1	4.8	4.4	21	19.8	1.1
1A	5.6	4.7	25	22.6	3.0
A	4.5	3.8	17	14.3	3.6
B	4.0	4.0	31	25.1	6.2
C	5.2	5.0	15	15.0	.3

Various concentrations of honey were used in determining the amount of alcohol produced by honey yeasts. In no case was the

production over five per cent. Thus, honey yeasts may be classed as low alcohol producers.

NATURAL FERMENTATION OF HONEY. In all of our honey work, we have observed only three naturally fermenting honeys that were liquid throughout and these samples were very thin, having a high moisture content. All of the rest of the samples we observed (around forty) were granulated or partly so but not solid. From these observations we believed that fermentation and granulation went hand in hand and perhaps granulation of honey brought about conditions which were favorable for the fermentation.

One of our early experiments was to inoculate samples of pasteurized honey with pure cultures of honey yeasts. As long as the honey remained liquid, no noticeable fermentation took place but after a year and some after two years when granulation commenced, the samples began to show signs of fermentation.

When honeys granulate coarsely a liquid forms around the crystals. Honey in this condition is easily separated and the moisture content of the liquid and of the crystals determined separately.

The moisture determination of several honeys are here given. One is a fermenting honey and the other, a heated sample of honey which granulated coarsely after a year in storage.

	Moisture	
	FERMENTED	NOT FERMENTED
	%	%
Liquid layer above crystals	18.33	20.8
Crystals below liquid	9.39	11.75

The granulation of honey explains why fermentation can take place in so-called ripe honeys. When granulation takes place, the dextrose settles out and contain less moisture than the original honey. Thus some extra moisture is given to the liquid portion of the honey which further thins it, making it dilute enough so that yeasts which are present in the honey grow.

EXPLANATION OF PLATE 16

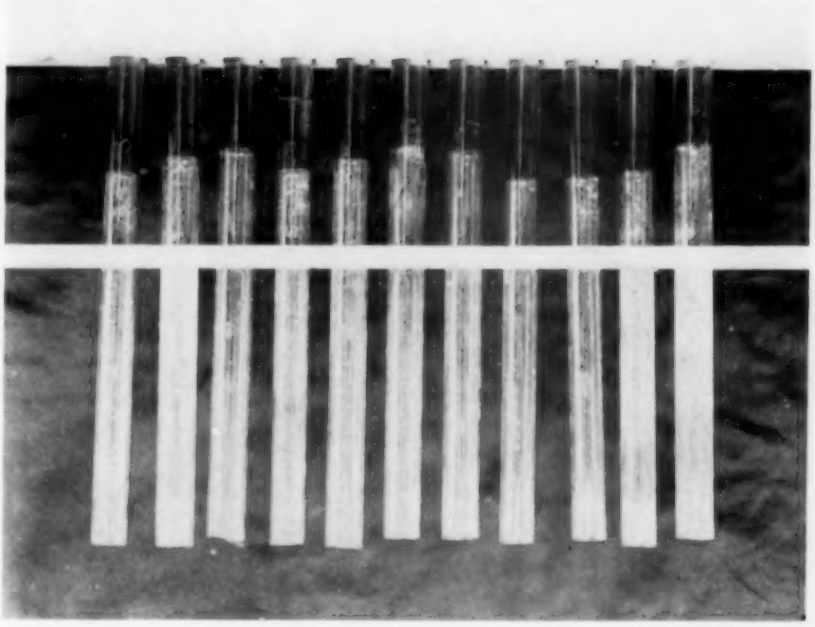
1.—A sample, showing the typical appearance of fermenting honey. The honey becomes divided into a lower granulated layer, an upper fluid layer with the surface covered with foam. See pages 436 and 437 for moisture and sugar analyses.

2.—The apparatus used for determining the amount of Carbon Dioxide given off during fermentation. The diluted honey after fermentation was analyzed for alcohol and acids.

3.—The sterile vaseline plug on the surface of 10 cc of a 2 per cent solution of raffinose, melezitose, starch, dextrin and yeast water as a check to determine their fermentability by honey yeasts. None of these substances are fermentable.

1

2



3

From previous experiments, we have found yeasts which are able to grow in high concentrations of sugar, widely scattered in nature. The spores are present in most honeys as our results show and when the proper conditions for their growth are brought about through the granulation of honey, the yeasts are able to grow and multiply. The products given off during their growth is what causes the off flavor to fermented honey.

Sugar analyses have been made of the liquid and granulated portions of fermented and unfermented honeys.

FERMENTED SAMPLE	CRYSTALS	LIQUID PORTION
Dextrose	36.78	28.37
Levulose	29.18	35.76
UNFERMENTED SAMPLE		
Dextrose	39.42	26.92
Levulose	29.14	37.50

PREVENTING FERMENTATION. In our experiments we have found that by heating honey to 160 degrees F., fermentation can be prevented. By heating honey to this temperature, the yeasts can be killed without holding the honey at that temperature for a period of time. In this case, heating kills the yeasts and prevents granulation for a year or so. Honey should be agitated while being heated so that nearest the container will not become overheated. Honey treated thusly will not be injured in flavor or color.

Unheated honey can be kept in storage at temperatures below 52 degrees F., for at that temperature yeasts will not grow and multiply.

SUMMARY. It is now a well known fact that honey fermentation is caused by yeasts. The fermentation process is slow, extending over a period of six months to a year. Carbon dioxide, rarely over five per cent alcohol and a non-volatile acid are the by products which cause the off flavor to fermented honeys.

When honey granulates conditions are brought about which are conducive to the growth of yeasts.

Honey fermentation can be prevented by heating to 160 degrees F.. or by holding honey at temperatures below 52 degrees F.

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Phillips: What was the procedure in crystal experiment?

Marvin: I melted crystals and poured on dish of white sand and heated in electric oven until constant weight was acquired.

STUDIES ON THE SUGAR CONTENT AND YIELD OF NECTAR FROM DIFFERENT VARIETIES OF *GLADIOLUS PRIMULINUS*

By O. W. Park, *Iowa Agricultural Experiment Station, Ames, Iowa*

Abstract

Studies made upon nectar from more than 25 varieties of *Gladiolus primulinus* showed that, while the percentage of sugar in nectar from different varieties varied within comparatively narrow limits, certain varieties characteristically yielded two and three times as much nectar as did certain others.

It has long been recognized that certain species of honey plants produce more honey than others but it has not been known whether all varieties of a given species yield equally well. In an effort to throw light on this question, studies have been made during two summers on a total of more than 25 horticultural varieties of *Gladiolus primulinus*, grown in the formal gardens at Iowa State College. *Gladiolus* is not an important source of honey but it is visited freely by honeybees and, in general, is well adapted to the needs of this problem.

A considerable number of variable factors outside of the plant itself, influence the production of nectar. For the sake of brevity, these may be grouped and referred to as light, air and soil factors. Differences due to variations in light and air conditions were reduced to a minimum by collecting each group of samples within a brief period, usually lasting from 30 to 40 minutes, in the early afternoon, which is the time of day when light and air factors normally are most nearly constant. The soil factors were considered uniform for the following reasons. The same general section of the garden has been devoted to the growing of Gladioli for several years. The area involved was very limited and the relative location of the several varieties was different for the two seasons.

Differences due to variations in the plants and flowers, other than varietal differences, were overcome to a considerable extent by taking composite samples composed of the nectar from 25 individual flowers.

Four groups of samples were taken in 1928 and a similar number in o929, each group containing samples secured from 20, or more, varieties. Owing to the preliminary nature of this study, only five varieties were represented in every one of the groups, hence, only these five are considered in this paper.

In order to provide a basis for comparing these varieties, three arithmetic means were determined for each variety, as follows:

(1) Quality of nectar (per cent of sugar)
(2) Quantity of nectar per flower
(3) Sugar yield per flower

When compared as to quality of nectar, the results indicate that further data will be required before it can be determined definitely whether certain varieties characteristically produce richer nectar than others. There are indications, however, that such probably is the case, altho the differences may not be great.

The quantity of nectar yielded by the highest producing variety was just three times that of the lowest, while the production of the other three varieties fell about a point approximately half way between the extremes just indicated.

In sugar yield, the rankings were the same as for quantity of nectar except that the varieties which ranked, respectively, 2nd and 3rd in nectar production, exchanged places when compared as to sugar yield. The weight of sugar obtained from the highest producer was nearly three times that obtained from the lowest, and the yields of the remaining three varieties again fell about mid-way between the extremes.

It may be tentatively concluded, therefore, that certain varieties of *Gladiolus primulinus* yield considerably more nectar than others and that, under similar conditions, the amount of sugar produced depends to a greater extent upon the quantity of nectar produced than upon its quality. These results suggest the desirability of similar studies on other and more important honey plants. If, for instance, certain varieties of sweet clover or alfalfa should be found superior to others of the same species for honey production, a new avenue for increasing the honey crop will have been opened.

VARIATION IN THE CONCENTRATION OF FLORAL NECTARS

By O. W. PARK, *Iowa Agricultural Experiment Station, Ames, Iowa*

ABSTRACT

A preliminary report on the extent to which variation has been found in the concentration of floral nectars.

Studies on more than 2000 samples of floral nectar have shown marked differences in the percentage of sugar contained. The causes of such variation will be discussed in a future publication. The purpose of this paper is to make a brief preliminary report on the extent to which variation has been found in the sugar content of floral nectars. Sugar concentrations were determined by means of an Abbé refractometer.

The writer[1] has previously shown that the sugar content of nectar from a given plant species, varies from hour to hour thruout the day. While all species studied so far, appear to show this diurnal fluctuation, individual species differ as to the range thru which such variation occurs. Variations other than diurnal fluctuations, would be most readily discovered from data into which diurnal variation did not enter. For this reason, samples to be compared were collected within the shortest possible time, two persons often being engaged in collecting simultaneously. Data thus obtained form the basis for the remainder of this discussion.

Composite samples of nectar, taken almost simultaneously from a number of different varieties of *Gladiolus primulinus* growing side by side, showed some variation but within comparatively narrow limits. Further data will be necessary before a definite statement can be made on this point.

Individual nectar samples taken in rapid succession from individual flowers of a single horticultural variety of *Gladiolus primulinus*, were compared as to sugar concentration. Three groups of 30 samples each, gave coefficients of variability of 27, 28 and 38 per cent, respectively.

In order to obtain data on the variation from floret to floret of the same umbel, nectar samples from *Asclepias syriaca* were used. Ten samples, each from a different floret of the same umbel, were taken for comparison. Coefficients of variability, determined for 26 such groups of samples, showed a minimum figure of seven per cent, a maximum of 32 per cent and a mean of 14 per cent.

Thus the concentration of floral nectar has been found to vary from

[1]Park, O. W. The Influence of Humidity upon Sugar Concentration in the Nectar of Various Plants. JOUR. ECON. ENT. 22:534–544. 1929.

hour to hour, from species to species, flower to flower and even from floret to floret in the same umbel.

PHILLIPS: Will you give us the color of the flowers? I wondered if the dark reds would not run higher temperatures.

PARK: No, I cannot tell you the colors. I hope to get more data on it, but am merely getting under way. I do not feel it is a proven fact yet; I simply present it as a progress report, an indication of what we are trying to do and a study of sweet clover, buckwheat and white clover.

MILUM: Has any attempt been made to take flowers at the same degree of maturity?

PARK: No.

VARIATIONS IN TIME OF DEVELOPMENT OF THE HONEY BEE

By VERN G. MILUM, *University of Illinois*

ABSTRACT

Studies made at the Wisconsin Experiment Station in 1924–1925 show variations, partly correlated to temperature, in the period from egg laying to capping of worker brood cells from less than 8 days to more than 11 days, majority being capped between the 8th and 9th days. Variations for complete development ranged from less than 19 7/8 days to more than 24 days. One set of experiments showed approximately 75 per cent of 4094 workers completing their development in less than 21¼ days. In another more definitely controlled set of 2602 individuals, 94 per cent emerged in less than 21 days with an average developmental period of approximately 20½ days.

The information herewith submitted has been taken from data secured by the writer in a study of colony temperatures at the Wisconsin Agricultural Experiment Station during the summers of 1924 and 1925, under the direction of Professor H. F. Wilson, of the Department of Economic Entomology to whom the writer is indebted for suggestions and the use of equipment and colonies. A part of the 1924 results were published in the *American Bee Journal*, Vol. 65, pp. 368–370.

In the course of a study of the temperature maintained in normal colonies under brood rearing conditions in the spring of 1923 it was found that the temperature of the brood rearing areas varied considerably from the temperature of 93°F. usually given by most writers. The records show that on April 11, 1923 none of five colonies with various types and amounts of protection had temperatures above 90.2°F., while 76.3°F. was the lower limit of the brood rearing area in a colony without any packing or protection. Although the temperatures of the brood areas generally varied between 90° and 95°F., it was

apparent that the queen often extended her egg laying activities to colder points. Temperatures from 95 to 97.5°F. were recorded but at these higher temperatures the bees were always hanging out at the entrance, indicating undesirable conditions.

With the facts just stated in mind, the question arose as to the amount of variation in the periods of the developmental stages under the extremes of temperature of the brood nests. A survey of the literature upon this question shows many differences of opinion among the earlier writers although many suggested variations depending upon the weather or temperature. In recent statements upon the subject, 16, 21 and 24 days are given as the length of time for the complete development of the queen, worker and drone honey bee, respectively. However, in none of these writings reviewed has a statement been found giving the results of actual controlled observations. Accordingly experiments with the worker honey bees were conducted during the summers of 1924 and 1925 with colonies each equipped with 44 copper-constantine thermocouples of which the temperatures could be determined by a potentiometer pyrometer. This apparatus and method are described in Research Bulletin 75 of the Wisconsin Agricultural Experiment Station.

In the 1924 experiments, frames of worker eggs were obtained by inserting brood free frames into the centers of strong colonies of bees for approximately 24 hour periods. The number of eggs laid that actually completed development as determined by counts made from photographs varied from 82 to a maximum of 803 or a total of 4094 on the nine frames used, as indicated in Figure 46. At the end of the egg laying periods these frames were inserted at definite positions in the brood nest of the experimental colonies with different degrees of protection and hence of temperatures maintained within their respective brood nest. These frames were kept surrounded with brood of all ages, to avoid neglect but the queens were confined to the upper body to prevent further egg laying.

At the time of capping of the brood the frames were removed and photographed on successive days until all cells were capped and then again at the time of emergence. In photographing, the frames of brood were taken into the warm laboratory to prevent chilling, and were photographed behind a dummy frame marked off by wires into inch squares which facilitated the counting of the individuals at a later time. Because of lack of time, the colony temperatures were usually recorded not more than once each day although at various hours. The temperatures given in the tables of Figures 46 and 47 are the averages of these

Development of the Honey Bee Worker
Capping of Cells
Emerging of Adults
Total Present
Days-7 June, 1924
Graph No.
Colony No.
Frame No.
No. Bees
Av. Temp
Hours Capping
No. Bees = 353
Percent = 8.6
2785
680
784
192
705
172
39
9
7
1
2.5
0.5
0.2
0.02
(16 Bees not emerged at Termination)
Expressed as total maximum time including 23-25 hour egg laying period and interval to time of photographing brood frame indicated by x's.
Accumulative totals of bees reaching the stage of development are expressed as percent of total for the frame.

FIG.—46

daily readings during the developmental periods which are probably quite relatively correct.

Figure 46 is an attempt to graphically represent the data obtained in the 1924 series of experiments. At the left the time of capping of the worker cells and at the right the time of emergence is indicated, each separate hive representing the bees on the particular frame designated by letters A to I. The information as to the colony and the particular location of that frame in the hive are given in the chart in the bottom center of the Plate. Additional information given there is the number of bees per frame, the average temperature of the thermocouples surrounding the brood during the period of development and the period of egg laying.

The accumulative totals of bees on each separate frame reaching the particular stage of development at the time the photographic records were made are graphed against the periods of time in days from the laying of the eggs which is the maximum possible time. Owing to the long period of egg laying used in 1924 (23–25⅓ hours) and the 24 hour period between most of the daily examinations the information obtained is not vert definite.

However, a study of Figure 46 will show that between 70 and 98 per cent of the bees on frames A to G were capped over in less than nine days, even counting the entire egg laying period, while on frame A, 28 cells or 4.4 per cent were capped in less than seven days and 22 hours. Many cells on Frame B were probably capped in less than eight days since 26.3 per cent or 92 cells were sealed before a maximum time of eight days 1½ hours. On the other hand with frame I, only one cell had been capped at the maximum of 10 days and the last cell of 82 on the frame had not been sealed at the end of 12 days and 15 minutes. Even if this particular egg were laid at the end of the egg laying period, it could not have been capped in less than 10 days and 23 hours.

For the maximum time required for emergence of adult worker the graphs at the right of Figure 46 show that 8.6 per cent of the total of 4094 bees emerged in less than 20 1/12 days, while an additional 68 per cent had emerged in a maximum period of less than 21¼ days. With frame A, of a total of 627 bees, 137 or 21.8 per cent actually emerged in less than 19⅞ days. With frame I with an average temperature of 88.5° F. no individuals had emerged in 22 days, while the last bee required at least 24 1/12 days.

Further experiments were conducted in 1925 along the same lines, but the period of egg laying was reduced to exactly six hours, the number of eggs obtained on the 11 experimental frames varying from 159

to 357 with observations on a total of 2602 bees actually recorded, as shown in Figures 47. Three colonies were used for developing the brood, but owing to the strength of the colonies and the favorable weather conditions the variations in temperature were not as great as in the 1924 experiments, hence the limits of the complete developmental periods cannot be expected to be as great.

In preparing Figure 47, the minimum, average and maximum periods of development for each group of bees emerged are graphed separately. The minimum curves are partly theoretical in that the beginning point of each curve was arbitrarily set by subtracting 18 hours from the maximum for each particular group of the first emerged bees. Likewise, the beginning points of the average curves are partly theoretical since they are the average of the theoretical minimum and the true maximum. However in both the minimum and average curves the second points and all intervening to the last point are exactly true. The error induced by this arbitrary method is shown by the observation for one particular frame J of this group on which the first bee was starting to gnaw the capping at the first examination and at the last examination the last bee was just crawling out of its cell. In this case the method used gave an error of 12 hours for the minimum curve and six hours for the average, but owing to larger numbers of bees having emerged on the other frames at the first examination, the errors are not as great for these beginning points.

No records were kept of the time of capping of the brood but the smallest maximum period recorded for complete development was 20⅙ days for two bees on frame K. On the remaining frames numbers of workers varying from 5 to 247, a total of 660 or 25.3 per cent had emerged at the first examination or in a maximum period of 20 days 5¼ hours to 20 days 6⅔ hours. No doubt, many of these bees, such as those with the greater number emerged at the first examination (H, C, F.) actually required less than 20 days.

As shown by the maximum curve on Figure 47, of the 11 frames in the 1925 experiment, all had 81 per cent or more of the workers and all but two (E, D.) had between 90 and 100 per cent of their totals developed in less than 20 days 23 hours and 50 minutes as a maximum. The combined totals for all of the frames show that 1772 or 68.1 per cent of the 2602 emerged in less than 20 days 23 hours and 50 minutes, which added to the 25.3 per cent emerging in less than 20¼ days gives a combined total of 93.46 per cent emerging in less than 21 days. Since the second points are correct for the minimum and average curves of Figure 47, the conclusion can be drawn that 93.46 per cent of the bees

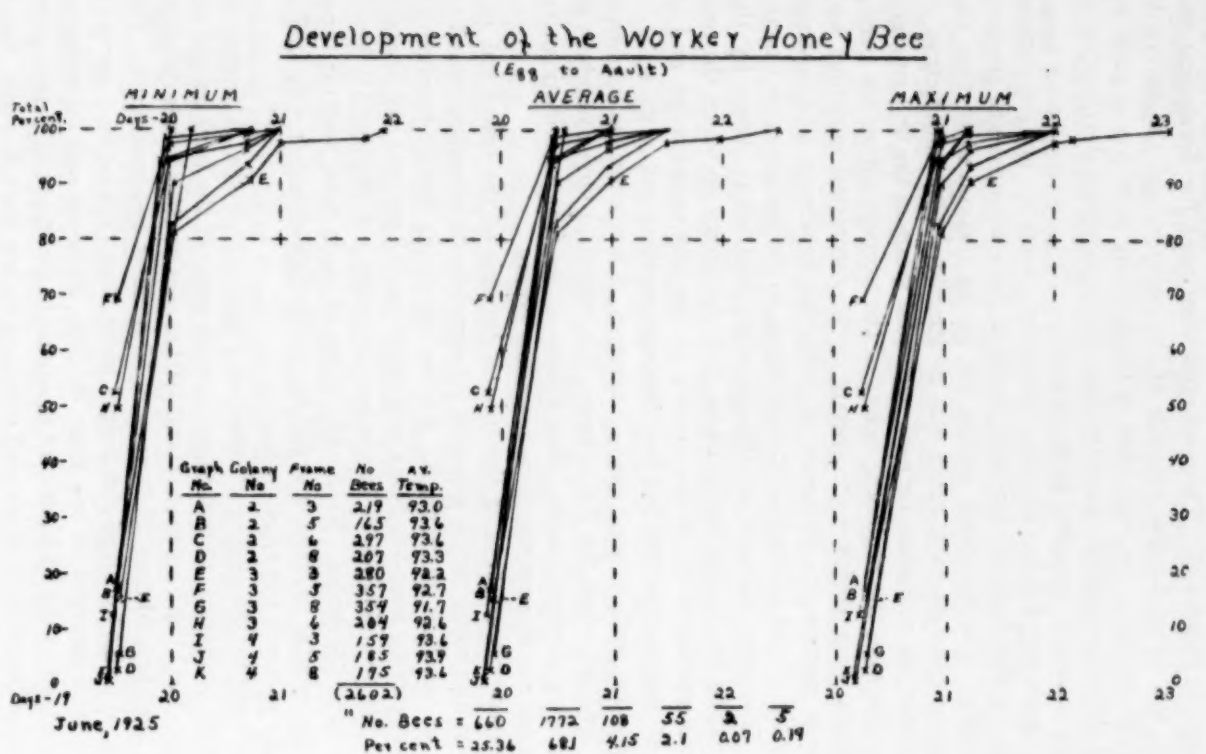
Development of the Worker Honey Bee
(Egg to Adult)
MINIMUM
AVERAGE
MAXIMUM
Total Percent. /100
Days - 20
21
22
23
90
80
70
60
50
40
30
20
10
0
Graph No.
Colony No
Frame No
No Bees
Av. Temp.
A 2 3 219 93.0
B 2 5 165 93.6
C 2 6 297 93.6
D 2 8 207 93.3
E 3 3 280 92.2
F 3 5 357 92.7
G 3 8 354 91.7
H 3 4 304 93.6
I 4 3 159 93.6
J 4 5 185 93.9
K 4 8 175 93.6
(2602)
No. Bees = 660 1772 108 55 2 5
Per cent = 25.36 68.1 4.15 2.1 0.07 0.19
Days - 19
20
21
22
23
June, 1925

FIG.—47.

under experiment had completed their development in an average time of 20½ days.

As in the 1924 experiments, one frame in particular showed considerable lengthening of the developmental period. While at least 43 bees or 15.3 per cent of the bees on frame E emerged in less than 20 days 6⅔ hours, one unemerged bee was active beneath its capping after a minimum period of 22¾ days.

Combining the results of the experiments for the two years, the following deductions can be stated. Upon observations of the developmental period of the workers of the honey bee the time of capping of the brood cells varied from less than eight days to more than 11 days, although the larger numbers were capped between the 8th and 9th days from the laying of the egg. Some actually emerged in less than 19⅞ days while others required more than 24 days for complete development from egg to adult. In one set of experiments, 74.6 per cent emerged in a maximum time less than 21¼ days, while in a more definitely controlled experiment, 93.46 per cent emerged in less than 21 days or an average developmental period for this portion of 20½ days.

THE RATE OF GROWTH OF WORKER, DRONE AND QUEEN LARVAE OF THE HONEYBEE, *APIS MELLIFERA* LINN.[1]

By HENRY A. STABE, *Assistant Professor of Entomology, Louisiana State University, Baton Rouge, Louisiana*

ABSTRACT

The growth rate of honeybee larvae was determined by weighing larvae individually or in groups at definite age intervals from hatching till maximum size was reached.

The growth rate of the honeybee larvae was determined by weighing larvae of different ages from those just hatched to the mature larvae. A discussion of methods used to obtain larvae of known age of the three different kinds follows.

WORKER LARVAE. A two-story observation hive with queen excluding zinc between the upper and lower story was made up and strengthened by the addition of bees until both combs were occupied. The upper story, in addition to having the glass sides, was provided with screen wire, 12 meshes to the inch, on the inside of the glass. It was found that, if the operator were careful not to breathe on the bees, the bees would continue to work without interruption when the glass

[1]The work being reported in this paper was done at Iowa State College, Ames, Iowa during the summer of 1929.

was removed. Small sticks of wood were cut of such size that they could be inserted tightly into the meshes of the screen with their inner ends entering the cells of the comb, for about one-half inch. As the queen left a cell after laying, one of these sticks was inserted into the opening of the cell thru the screen. The screen served to hold the stick which was used only as a temporary mark. When the queen finished laying a series of eggs and rested, each of these cells was marked by means of a quick drying lacquer applied with a stick to the sides of the cell. It was found that the lacquer remained on the wall of the cell for several weeks and did not interfere in any way with the work of the bees after it had dried.

The queen was observed for two hours and the cells in which she laid were marked in the same manner and constituted one lot. Since the incubation period of the honeybee egg is known to be approximately 76 hours, the age of the larvae could be very easily determined. A total of 25 lots of eggs was secured in this way. The times of weighing the larvae of the different lots were so arranged that lots of larvae at age intervals of six hours from zero to 144 hours were obtained. All of the larvae in a given lot were weighed at one sitting in order to eliminate as nearly as possible the effect of change of environment due to removing the comb from the hive. The larvae were reared in the brood chamber of a strong colony. Most of the older larvae were weighed singly and the results have been statistically treated.

Queen Larvae. The queen and the observation hive used in securing the worker larvae were also used to obtain the queen larvae. The queen was allowed to lay in the frame in the upper story of the observation hive for a period of about 21 hours. The frame was then removed and placed over an excluder in a strong colony and another frame was placed in the observation hive. This was done each day.

Three days after placing a given frame over the excluder most of the eggs had hatched and the young larvae in the cells varied in age from zero to 18 hours. The smallest of these larvae were selected and grafted into queen cell cups, a total of 64 cells on four bars being grafted each day.

Four strong colonies had previously been prepared for queen rearing and each received one of these bars. This was repeated each day until each queen rearing colony had six bars of queen cells. Five and one-half days after the first cells were grafted, the cells from two of the colonies were removed and the larvae were weighed individually. Twelve hours after this the cells from the other two colonies were weighed. This

resulted in obtaining lots of queen larvae at age intervals of 12 hours from 12 to 144 hours. This was repeated until five such series of larvae had been obtained.

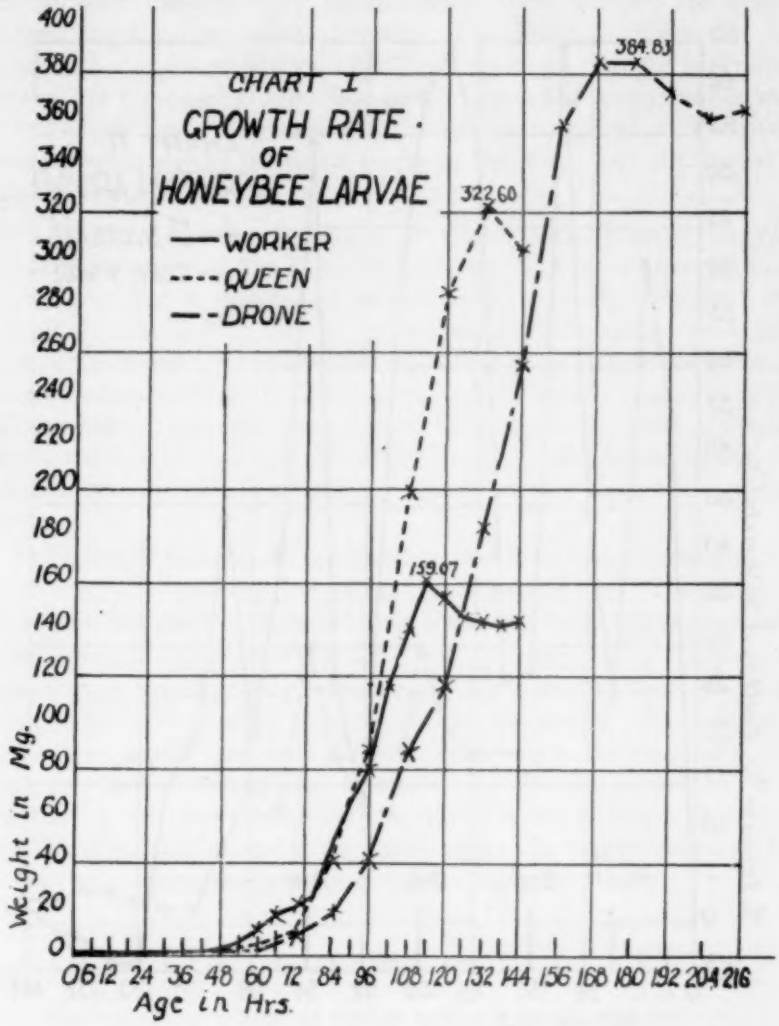

FIG.—48

DRONE LARVAE. A frame containing drone foundation was inserted into the brood chamber of a strong colony. In a short time the bees had drawn out the foundation and the queen had laid some eggs. The frame was removed and the eggs were destroyed. The frame was then

replaced and 12 hours later was again removed. The cells containing eggs were marked by means of lacquer. Usually only 100 cells were marked and the eggs in the unmarked cells were destroyed. This was

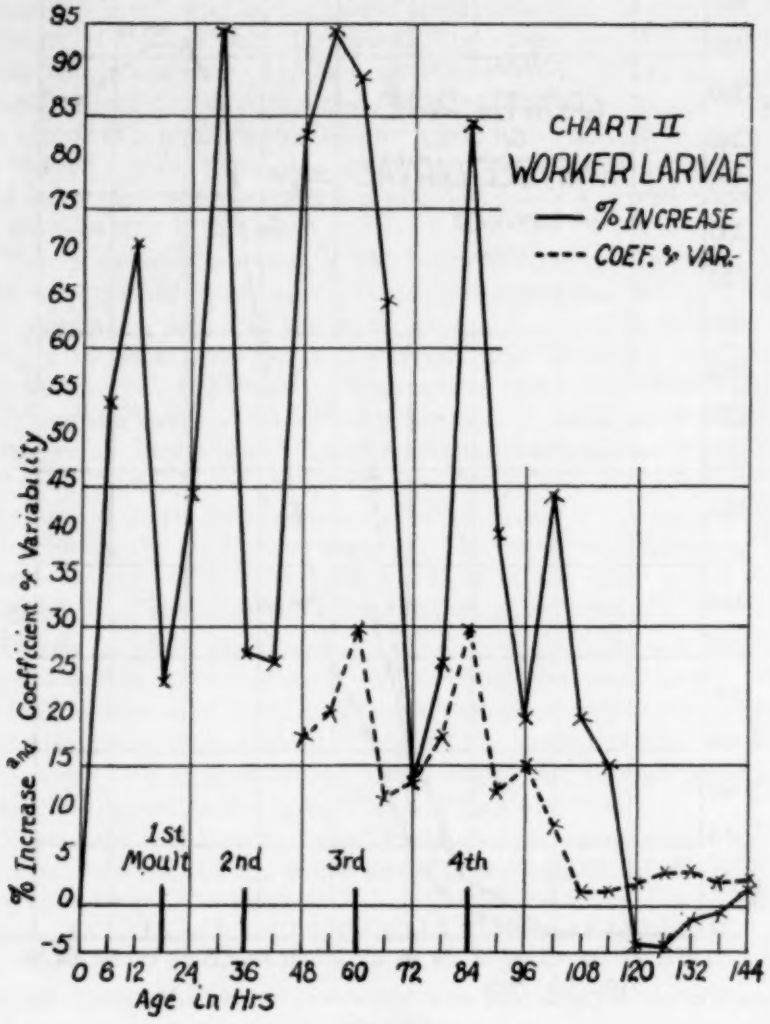

FIG.—49.

continued with this frame and others until 19 lots of eggs were obtained. The larvae were weighed at such times that lots of larvae at age intervals of 12 hours from zero to 216 hours were obtained.

RESULTS. Results are recorded in Tables 1, 2 and 3 and are shown graphically in Figures 48 and 49. These show that the increase in weight of honeybee larvae is relatively slow during the first few days. Later the increase becomes very rapid. When these weights are plotted against the time an S-shaped results as is shown in Figure 48. The maximum average weight of 159.07 mg. for worker larvae is attained in the 114 hour age group. For queen larvae the maximum average is 322.60 mg. and it is attained in the 132 hour age group. The maximum average weight for drone larvae is 384.+mg. and is attained in the 168 and 180 hour age groups.

COMPARISON OF GROWTH RATE OF QUEEN AND WORKER LARVAE. From Tables 1 and 2 and Figure 48, it is seen that for the first 48 hours the growth rate of queen and worker larvae is nearly identical. Following this the growth rate of the worker larvae is much faster than that of the queen larvae so that at 60 hours the worker larvae are more than twice as heavy as the queen larvae. At 72 hours the worker larvae still are heavier than the queen larvae. At 84 hours the average weights of the two kinds of larvae are nearly the same and following this the queen larvae increase in weight much more rapidly than do the worker larvae.

In Figure 49 the percentage increase over previous weight and the coefficient of variability are plotted against the age. The times at which the first four larval moults occur are also indicated in the figure.

As shown in the chart the growth rate, as indicated by the percentage increase, varies greatly from one six hour period to another. Other workers have shown that, in other insects, the growth rate is retarded just before, during, and after a moult. Referring to the chart, it is seen that, for the first two moults, this holds true for the honeybee. With the third and fourth moults the retardation seems to occur later. One would expect this as the percentage increase in reality measures the growth rate during the preceding six hour periods.

CONCLUSIONS

1. The maximum weight of worker larvae is attained between 114 and 122 hours.
2. The maximum weight of queen larvae is attained between 122 and 134 hours.
3. The maximum weight of drone larvae is attained between 164 and 184 hours.

4. The growth rate of worker larvae varies greatly during a given instar, being greatly reduced just previous, during, and after a moult.

5. The growth rate of worker and queen larvae is nearly identical for the first 48 hours.

TABLE 1. WORKER LARVAE

Date	Age in Hours	No. of Larvae	Total Weight mg.	Ave. Weight mg.	Increase Over Previous Weight	% Inc. Over Previous Weight	Coefficient of Variability
July							
16	0	70	7.7	0.11			
"	6	50	8.7	0.17	0.06	54	
"	12	50	14.3	0.29	0.12	71	
"	18	60	21.6	0.36	0.07	24	
"	24	50	26.0	0.52	0.16	44	
"	30	45	45.5	1.01	0.49	94	
"	36	50	64.4	1.29	0.28	27	
"	42	55	89.9	1.63	0.34	26	
"	48	16	48.5	3.03±0.09	1.40	83	17.80±2.17%
"	54	20	117.5	5.87±0.19	2.84	94	20.70±2.30%
"	60	23	255.8	11.12±0.48	5.25	89	29.94±3.25%
"	66	20	366.0	18.30±0.33	7.18	65	11.58±1.24%
"	72	22	452.3	20.56±0.40	2.26	13	13.18±1.37%
July							
15	78	34	881.3	25.92±0.55	5.36	26	18.02±1.51%
"	84	27	1344.3	47.79±1.88	21.87	84	29.82±2.99%
"	90	20	1335.1	66.76±1.25	18.97	40	12.12±1.30%
"	96	17	1363.2	80.19±1.98	13.43	20	14.64±1.76%
"	102	15	1734.2	115.62±1.79	35.43	44	8.58±0.92%
"	108	8	1111.2	138.90±0.79	23.28	20	1.50±0.25%
"	114	31	4930.7	159.07±0.36	20.16	15	1.84±0.16%
"	120	33	5028.7	152.38±0.62	6.48[1]	4.2[1]	2.32±0.19%
"	126	31	4512.7	145.57±0.62	6.81[1]	4.5[1]	3.48±0.30%
"	132	29	4147.9	143.03±0.65	2.54[1]	1.7[1]	3.55±0.31%
"	138	26	3687.6	141.83±0.50	1.20[1]	0.84[1]	2.60±0.24%
"	144	28	4030.3	143.94±0.51	2.11	1.5	2.71±0.24%

[1]Denotes loss.

TABLE 2. QUEEN LARVAE

Age in Hours	No. of Larvae	Total Weight mg.	Average Weight mg.	Coefficient of Variability
0	70	7.7	0.11	
12	45	12.9	0.29	
24	47	27.8	0.59±0.026	44.07±3.61%
36	45	57.7	1.28±0.028	21.09±1.62%
48	56	173.7	3.10±0.094	33.55±2.38%
60	28	131.3	4.69±0.16	27.08±2.65%
72	33	382.7	11.60±0.55	39.48±3.77%
84	36	1523.2	42.31±1.79	37.13±3.33%
96	37	3220.7	87.05±2.01	20.57±1.68%
108	31	6156.4	198.59±5.02	20.52±1.83%
120	31	8850.3	285.50±5.81	16.51±1.40%
132	38	12,258.9	322.60±2.52	7.03±0.81%
144	42	12,721.4	302.89±1.68	5.26±0.39%

TABLE 3. DRONE LARVAE

Date	Age in Hours	No. of Larvae	Total Weight mg.	Average Weight mg.
1929				
Aug. 5	0	70	7.7	0.11
5	12	100	25.0	0.25
5	24	60	23.3	0.39
5	36	80	86.2	1.08
5	48	85	171.0	2.01
5	60	75	247.8	3.30
Aug. 1	72	65	551.0	8.45
1	84	60	1148.2	19.13
1	96	63	2578.6	40.93
Aug. 16	108	154	13402.3	87.03
Aug. 1	120	8	922.4	115.30
1	132	63	11596.7	184.07
1	144	56	14207.7	253.71
1	156	46	16413.6	356.82
1	168	65	25010.8	384.78
Aug. 16	180	120	46179.4	384.83
16	192	115	42517.7	369.72
16	204	100	36016.1	360.16
16	216	105	38259.0	364.37

MR. HERMS: This paper interests me a great deal. Some years ago I worked on the growth of fly larvae. The results of the work of this gentleman correspond very closely with the results of flesh fly larvae. Could not measurements be taken at more frequent intervals than six hours? Your percentage curve might be changed somewhat, although the general appearance conforms very nicely with the work which I did, but I would like to see you do it at intervals of two hours.

PRELIMINARY REPORT CONCERNING FACTORS RELATED TO CERTAIN OF THE GROWTH PHASES OF *Bacillus Larvae*

By ARNOLD P. STURTEVANT, *Laramie, Wyoming*

ABSTRACT

Little work has been done on the growth phases of *Bacillus larvae*, the cause of American foulbrood. In the past, forty-eight hours incubation of cultures has been considered sufficient to demonstrate absence or presence of vegetative growth on artificial culture media. The present investigation has demonstrated that within certain lower limits, as yet not definitely determined, the smaller the seeding of spores of *Bacillus larvae* on a given culture medium, the longer is the incubation period necessary to obtain germination and vegetative growth. This may account for discrepancies between reports of cultures made of scales from combs subjected to sterilization processes, and apiary results.

There has been little work done on the growth phases of *Bacillus larvae*, the cause of American foulbrood, although this subject has been of considerable interest to bacteriologists in the study of numerous other organisms. Because of the fact that *B. larvae* grows with diffi-

culty, if at all, on ordinary culture media, but requires the addition of special growth producing substances to the medium, such as sterile egg yolk (11) or such vegetable extracts as carrot extract (7) in order to obtain growth, there have been difficulties in the way of making a complete cultural study of the growth phases of this organism.

It has been stated (9) (7) that germination of spores and growth of *B. larvae* will take place on a suitable medium with 24 hours incubation at 37°C., but maximum growth is not obtained much before 48 hours. Because of this fact there has been a tendency in most of the bacteriological work with *B. larvae*, to accept a 48 hour period of incubation as standard and sufficient in the various procedures for the isolation and cultivation of this organism on artificial culture media. This practice has been used particularly in the case of the bacteriological examination of American foulbrood scales from infected combs that have been subjected to various sterilizing processes, although Jones (6) in early work along this line states that in reporting on the culturing of scales treated by various disinfectants, all cultures were examined daily up to 14 days before negative results were recorded. In general, however, it has been assumed as previously stated by the writer (10) that "when no germination of spores was observed, as a rule only one examination of the culture was made at the end of 48 hours incubation, since if there are any spores in a condition to germinate they will do so within that period."

Two other facts have been noted in connection with the isolation of many cultures of *B. larvae*, that can only be explained in the light of a study of certain of the growth phases of the organism. It has been found that the use of a heavy initial seeding of spore containing material on the surface of the proper solid culture medium is more successful in producing initial good growth than when relatively small amounts of spores are used, (9). It often has been found impossible to obtain any growth at all when only a small amount of spore containing material is inoculated onto the medium and with 48 hours incubation. Furthermore, occasionally scales are found in unsterilized combs that will produce no growth after 48 hours incubation even though presumably uniform cultural methods are used in all cases.

For several years field studies have been in progress in an attempt to determine the minimum amount of infectious material, i.e., the actual number of spores of *B. larvae*, necessary to produce American foulbrood in healthy colonies of bees. This has been done by feeding to series of experimental colonies varying numbers of spores of *B. larvae* suspended in uniform quantities of sugar syrup. The numbers of spores

fed ranged from a heavy inoculation that would cause disease in every case, down to the controls fed no spores at all. In order to obtain further information on the ability of small numbers of spores to germinate and grow in comparison with the field studies, a large series of cultures were made in the laboratory during the spring of 1929, using as the inoculating material a standardized suspension of spores of *B. larvae* diluted in the same proportions and containing the same numbers of spores as in the field experiments, including also numerous intermediate dilutions. Certain facts have become evident from this work that throw new light on some of the questions mentioned above, making it seem advisable to change certain laboratory procedures in the bacteriological work on American foulbrood. However, since this investigation has not yet been completed, only a brief description of the experimental work will be given, sufficient to bring out the facts that seem to be of importance.

PROCEDURE. A suspension of spores of *B. larvae* was obtained by placing approximately 75 untreated American foulbrood scales in a flask containing 50 cc sterile water and glass beads. After becoming softened the scales were macerated by shaking the suspension with the glass beads for one-half hour. The suspension was then filtered through two thin layers of sterile absorbent cotton into a second sterile flask in order to remove any remaining masses of scale material. The number of spores per cubic centimeter of this material was determined by means of a Helber bacteria counting cell as well as by a direct method of counting similar to that devised by Breed and Brew (1) for counting the bacteria in milk by means of the microscope. After the suspension of spores was standardized to contain approximately 5,000,000,000 spores per cubic centimeter, a series of dilutions was made from the standardized suspension in sterile distilled water, each succeeding dilution having a gradually smaller number of spores per cc than the preceding. Then 1 cc of each dilution was transferred by means of sterile pipettes into each of a duplicate series of tubes of a special solid agar culture media. The medium used was the yeast-carrot agar media of Lochhead (7) to each tube of which 20 drops, or approximately 2 cc, of sterile egg yolk was added before the agar was solidified in a slanting position. These cultures were incubated at 37°C., for periods of time varying from 48 hours up to ten days. When long periods of incubation are used, care should be taken that the culture media in the tubes does not dry out. This can be prevented by the addition to the culture tubes from time to time of a few cubic centimeters of a sterile broth of similar composition to the solid base medium described above, without the addition of the sterile egg yolk.

OBSERVATIONS. Starting with a seeding of 5,000,000,000 spores per cc inoculated on the slanted solid culture media, it was found that at the end of 48 hours, growth had occurred in the first culture tube containing 1 cc of undiluted spores from the stock suspension and in the first dilution culture tube containing 500,000,000 spores but not in the second dilution culture tube containing 50,000,000. Another series of dilutions was made then with intermediate dilutions, making the step in the numbers of spores between each dilution inoculated even smaller. After incubating this series 48 hours at 37°C., slight growth was obtained in the dilution culture tube containing 60,000,000. Then a similar series of cultures was inadvertently incubated for six days before being examined. In this series it was found that slight growth was obtained in the culture tube inoculated with 5,000,000 spores. Now another series of similar dilutions was run incubating for 10 days at 37°C. in which series slight growth was obtained in the tube inoculated with only 700,000 spores.

Therefore, although this investigation is yet incomplete and the figures given may vary somewhat with different strains of the organism and with variations in different batches of culture media, it was found that while the smallest number of spores in a seeding producing growth after 48 hours incubation was twelve one-thousandths of the number of spores in the original suspension of 5,000,000,000 spores, after ten days incubation, the spores in a seeding containing only fourteen one hundred-thousandths the number of spores in the original suspension, or approximately a number 100 times smaller than the minimum seeding giving growth after 24 hours incubation, would germinate and produce growth. In other words, it is evident that within certain limits the smaller the seeding of spores, the longer must be the incubation period in order to obtain growth.

Another angle of this same problem was observed during the same spring of 1929 in connection with experiments to determine how small a number of viable spores would produce growth in cultures from American foulbrood scales that had been removed from combs subjected to varying lengths of exposure to the action of formaldehyde gas. In several cases, cultures from scales that apparently were near the borderline between partial and complete sterilization showed no growth or only a very few rods germinating from spores but producing no visible vegetative growth when examined after 48 hours incubation. When as much of the scale mass as possible was removed from the original culture media inoculated onto fresh media, and incubated for another 48 to 72 hours, in several instances good growth was obtained. This

practically amounted to increasing the length of the incubation period. Unfortunately it was not possible to carry this line of observation further under more carefully checked conditions, although it is given here as an indication of the same phenomena discovered above.

DISCUSSION. Bacteria are known to pass through quite a definite cycle of growth, particularly when cells from an old culture are transferred to fresh culture medium. Only the initial stages of this cycle are of interest in relation to the work herein reported on *B. larvae*, no studies having been made so far as to the later phases of the growth curve. These stages have been described by various investigators (2) (5) somewhat as follows; the initial stationary phase during which no growth takes place, the logarithmic phase when the organisms begin to divide slowly at first, gradually accelerating, and so on through the complete cycle of growth. These initial phases as described by Buchanan (3) are more clearly marked with spores than with simple vegetative organisms since there is a period of varying length of time necessary for the spores to germinate and start vegetative growth after implantation in a suitable medium. It also has been observed that this initial period of apparent dormancy varies considerably with different organisms, the spores of some spore forming organisms remaining dormant in some cases for many days before starting growth (4).

Furthermore it has been observed by Henrici (5) that "various factors as temperature; the size, age and previous history of the inoculum; and the composition and nutrient value of the medium, influence the form of the growth curves of bacteria and "of the various factors which influence the rate of growth and form of the growth curve, the initial number of cells introduced into a unit volume of medium seems to be one of the most important." It has also been shown by Robertson (8) in studies of subcultures of certain protozoa, that growth apparently seems to be stimulated by the presence of other cells of the same type. Various theories have been proposed as to the nature of this stimulus (3) (5) but they will not be discussed at this time as more work is necessary along this line with *B. larvae*. It is known, however, that there are certain organisms, such as the pneumococcus, with which it is very difficult to obtain single-cell isolations.

In the light of such observations it is now easier to understand the results obtained with cultures of *B. larvae*. In the work herein reported the temperature of incubation was constant, 37°C., although the period of incubation was varied. The age and previous history of the spores was practically the same in all cases since the organisms were all obtained from dried down American foulbrood scales containing nothing

but spores. Therefore, it is evident that as the size of the seeding was decreased a point was reached where the numbers for some reason were too small to start growth within the 48 hours incubation period. However, by increasing the length of the incubation period, the minimum seeding that would produce growth was materially decreased. There seemed to be a point somewhat variable beyond which the seeding could not be reduced and obtain growth. Apparently the growth stimulus, whatever it is, had been reduced below the necessary minimum. Also with the smaller seedings the period of dormancy seemed to be lengthened, because where growth did occur, it did not become apparent until towards the end of the lengthened incubation period while with the larger seedings good growth occurred within 48 hours.

CONCLUSIONS. While these observations are only of a preliminary nature and much more work is necessary upon the entire subject, certain facts seem sufficiently evident from which to draw a few conclusions.

1. In order to obtain definite growth of *Bacillus larvae* in a minimum of time, a heavy seeding of viable spores on a suitable culture medium is necessary.

2. Within certain limits not yet definitely determined, the smaller the seeding of spores of *Bacillus larvae*, the longer is incubation period necessary to obtain vegetative growth.

3. Therefore, in culturing American foulbrood scales that have been subjected to various methods of sterilization in order to determine the efficiency of the sterilizing process, the period of incubation of the cultures should be increased to at least ten days if not more before negative growth results are reported.

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THE AMERICAN HONEY INSTITUTE

By KENNETH HAWKINS

Since its inception in March, 1928, the American Honey Institute has taken so active an interest in scientific research in beekeeping and particularly the use of honey as a food that the Institute deserves the consideration and support of every member of the A.A.A.S.

More recently, Dr. H. E. Barnard, director of the Institute, has been chosen by President Hoover to take a very active part in the child welfare work being fostered by the government. Dr. Barnard was formerly director of the American Institute of Baking and has active contacts with the research being done along these avenues. His present connections with several large food corporations in a scientific way give him additional contacts.

The Institute is fostering research on the use of honey as a food so that physicians may be supplied with reliable information regarding the food value of honey. Bakers are being supplied with recipes, enabling them to scientifically use honey in their products. Many large food packers are for the first time offering their products to consumers through recipes in which honey is playing a part, as a result of this scientific research fostered by the Institute.

The privilege of presenting this information so briefly is to more fully to acquaint you with the scientific work of the American Honey Institute in the hope you may feel justified in urging associations of honey producers in your territory to support the Institute, morally and financially. Mr. L. C. Dadant of Hamilton, Illinois, is the treasurer and Mr. L. W. Parks of Watertown, Wisconsin, is president. Let us help you in your bee and honey problems in any way we can.

PYRETHRUM AND SOAP, A CHEMICALLY INCOMPATIBLE MIXTURE

By R. C. ROARK, *Insecticide Division, Bureau of Chemistry and Soils, Washington, D. C.*

Much work done by entomologists and reported in the literature shows an apparent ignorance of the nature of the insecticidal constituents of Pyrethrum (*Chrysanthemum cinerariaefolium* Trev.). The compounds responsible for the toxic action are now known, and their chemical nature should be kept in mind in planning entomological tests.

The designation "oleoresin of Pyrethrum" is an old pharmaceutical term applied to the ether extract of Pyrethrum flowers. This extract contains a small quantity of volatile oil and a number of other constituents, of which two, known as Pyrethrin I and Pyrethrin II, contribute the characteristic insecticidal action of the flowers. The structure of these two compounds was first established by Staudinger and Ruzicka in work done from 1910 to 1916 but not reported until 1924, (Helvetica Chim. Acta., v. 7, pp. 177–259, 377–458, 1924) and the conclusions have been confirmed by LaForge (U. S. D. A. Bul. 824 rev., April, 1926, pp. 72–75); and Yamamoto (Chemical Abstracts, v. 20, p. 41, 1926). The pyrethrins both belong to a class of organic compounds known to chemists as esters. Esters are compounds formed by the combination of an acid with an alcohol. For example, the ester known as ethyl acetate may be formed by combining ethyl alcohol and acetic acid

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} + \underset{\text{Acetic acid}}{CH_3COOH} \rightleftharpoons \underset{\text{Ethyl acetate}}{CH_3COOC_2H_5} + \underset{\text{Water}}{H_2O}$$

The reaction is reversible, which means that in contact with water an ester is decomposed partially into its component parts—alcohol and acid. Heating greatly accelerates the speed of this reaction, the general rule being that the rate doubles for each increase of 10 degrees centigrade. Thus Pyrethrins I and II are probably decomposed by water 4 times as fast at 40°C. (104°F.) as at 20°C. (68°F.). Further, in the presence of an aqueous solution of alkali an ester decomposes more completely and more rapidly than in the presence of water alone, owing to the fact that the reaction is then irreversible, the liberated acid being bound by the alkali as fast as it is formed.

$$\underset{\text{Ethyl acetate}}{CH_3COOC_2H_5} + \underset{\text{Sodium hydroxide}}{NaOH} = \underset{\text{Sodium acetate}}{CH_3COONa} + \underset{\text{Ethyl alcohol}}{C_2H_5OH}$$

In entomological literature there are reported many tests made with pyrethrum powder in combination with soap, or with an alcoholic or other extract of pyrethrum combined with soap. Ordinary soap is a mixture of the sodium salts of higher fatty acids, especially oleic, palmitic and stearic acids. These soaps in dilute solution partially hydrolyze forming a dilute solution of sodium hydroxide, which in turn saponifies (decomposes) the Pyrethrins I and II. Many soaps made primarily for use as insecticides contain even an excess of alkali, in which case the Pyrethrins would be more rapidly decomposed. Pyrethrum extracts containing soap are on the market. These extracts are not anhydrous, but contain from 25 to 50 per cent water, under which conditions the Pyrethrins decompose slowly.

In apparent contradiction to the facts stated above many favorable results have been reported on the use of Pyrethrum flowers or a Pyrethrum extract in combination with soap. Probably these results have been obtained because the mixture was sprayed on the insects before the Pyrethrins had completely decomposed.

It must also be remembered that soap alone is a powerful insecticide against aphids, Japanese beetle (van der Meulen and Van Leeuwen, J. Econ. Ent., v. 22, p. 812, October, 1929) and many other insects. When soap and Pyrethrum extract are added to water the Pyrethrins (esters) begin to decompose. The decomposition is hastened by heat. The higher the concentration of alkali the greater and the more rapid is the decomposition; the longer the time of contact, the greater the decomposition.

Very careful insecticidal tests have been made by Staudinger and Ruzicka (ibid., pp. 453–8) and C. H. Richardson (U. S. D. A. Bul. 824 rev. April 1926, footnote p. 73) with the acids and alcohols which make up Pyrethrins I and II, but in all cases the insecticidal action of these was markedly less than that of the Pyrethrins. In other words when the Pyrethrins are saponified the resulting products are practically valueless as insecticides. The Pyrethrins are high priced insecticides. Pyrethrum flowers are now (March 1930) quoted at 35 cents per pound wholesale. Very few flowers contain more than 1 per cent of the two Pyrethrins, and the average is much less. Assuming a 1 per cent content of Pyrethrins in the flowers, the present cost of these constituents (unextracted) is about $35 per pound. It may be calculated that 1 gram sodium hydroxide will completely saponify 8.25 grams Pyrethrin I or 4.675 grams Pyrethrin II. Assuming Pyrethrin I and Pyrethrin II to be present in the flowers in a 50:50 ratio, three cents worth of lye (1 pound NaOH) will wholly destroy the insecticidal constituents of

$226.10 worth (646 pounds at 35 cents per pound) of Pyrethrum flowers. Such high priced insecticidal material should be handled with a knowledge of its chemical and physical properties. If soap *must* be used in combination with Pyrethrum or a Pyrethrum extract, the soap should be as nearly neutral as possible, no excess soap should be added, the solution should not be heated, and the solution should not be allowed to stand before being sprayed upon the insects. Failure to observe these rules will result in highly variable kills, owing to the variable decomposition of the Pyrethrins.

Pyrethrum is incompatible not only with soap but also with hydrated lime, lime-sulphur solution, sodium-sulphur and barium-sulphur combinations, dry lime-sulphur and other materials which dissolve in or are hydrolyzed by water to form alkaline solutions. Pyrethrum, or extracts thereof, should be sprayed in a solution, emulsion or suspension as nearly neutral as possible, and as soon as possible after being mixed with water.

The author believes that the addition of saponin, of sulfonated oxidation products of petroleum so successfully used with nicotine (Ind. Eng. Chem. v. 21, p. 542, June 1929), or other wetting or activating agents to Pyrethrum or a Pyrethrum extract (free from soap) will in most cases produce a mixture of at least as high toxicity as a mixture containing soap, and will have the advantage of being less readily decomposed.

In buying Pyrethrum flowers or extracts thereof it would be well if the purchaser would insist on a statement from the manufacturer giving the exact percentage of Pyrethrins present. Methods for the quantitative determination of Pyrethrins I and II have been proposed (Staudinger and Harder, Ann. Acad. Sci. Fennicae, *29A*, pp. 1–14, 1927; Tattersfield, Hobson and Gimingham, J. Agr. Sci., *19*, pt. 2, April 1929; Gnadinger and Corl, J. Am. Chem. Soc., *51*, pp. 3054–3064, 1929). While none of those methods have as yet been adopted by the Department of Agriculture, they represent a great advance upon previous methods and can probably be improved. An accurate and practical chemical method for the evaluation of Pyrethrum will doubtless soon be forthcoming.

A SIMPLE AND EFFECTIVE ANT TRAP FOR HOUSEHOLD USE

By R. T. COTTON and G. W. ELLINGTON, *U. S. Bureau of Entomology, Washington, D. C.*

ABSTRACT

Directions are given for making a simple yet effective ant trap for use in houses.

While suppressing an outbreak of the little red ant or Pharaoh's ant, *Monomorium pharaonis* L., in the kitchens of the White House, the writers designed and tested a container for a poisoned syrup that is so simple and convenient and gives such excellent results that it seems worth while describing.

The container for this ant poison consists of an ordinary pill box the interior of which has been washed with a solution of hot paraffin to make it water tight. As shown in Figure 50, A and B, four small sec-

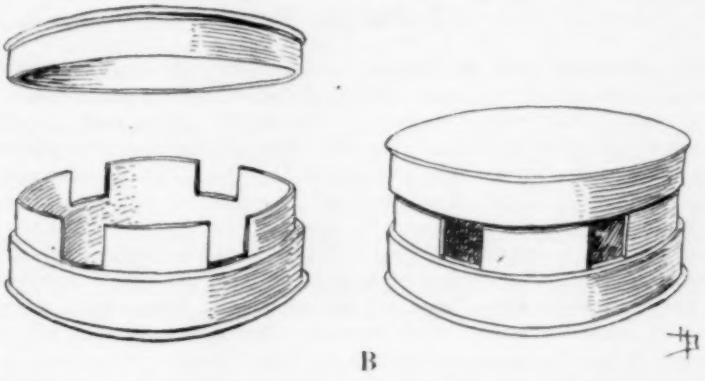

FIG. 50.—A simple ant trap made from an ordinary pill box. A, pill box with cap removed to show the notches cut in inside collar; B, pill box with cap in place, ready to use, showing openings for the ants to enter.

tions of cardboard are removed from the inner circular collar, over which the top or cap of the pill box fits. When the container is in use, the top of the pill box is partially raised, exposing four small openings where the cardboard has been cut away, and through these the ants can enter to obtain the syrup. The contents of the box are protected by the cap from dust and excessive evaporation, and pet animals are unlikely to be attracted to such a closed container.

The containers, being small, are relatively inconspicuous and can be placed around wherever the ants are troublesome. When not in use it is a simple matter to press down the covers and set the boxes aside until needed.

The boxes should be about two-thirds filled with small pieces of blotting paper, to which is added a small quantity of a poisoned syrup. The syrup may be renewed as often as necessary.

In testing these containers, the writers used the poisoned syrup made with thallium sulphate, described by Popenoe in *Science*, Volume LXIV, No. 1665, page 525 (1926). It consists of 1 pint of water, 1 pound of sugar, 27 grains of thallium sulphate, and 3 ounces of honey, the whole being thoroughly stirred and brought almost to a boil. Since thallium sulphate is a powerful and insidious poison, care should be taken not to breathe the vapors given off by the syrup as it is being prepared.

When used in the containers described above, the writers found this syrup to be exceedingly effective against the little red ant that is so common in dwellings. Infestations were wiped out within a few days.

Scientific Notes

The Predaceous Habit of *Cyrtopeltis varians* Dist. On August 16, 1929, while making observations on the corn earworm, *Heliothis obsoleta* Fabr., a field of Perique tobacco which had been cut in June and the stubble left for seed production was examined and several adults and nymphs of *Cyrtopeltis varians* were observed with their beaks inserted in the eggs of species of *Heliothis*. This hemipteron was fairly abundant in both the adult and nymphal stages and moved about more or less constantly, rather swiftly at times, through and over the tops of the plants. The manner of their movement indicated that they were searching for eggs and young larvae of *Heliothis*. The efficient work of the predator was further evidenced by the scarcity of *Heliothis* larvae upon the tobacco plants. Occasionally a larva of an advanced instar was found. From material collected and placed in the laboratory at Baton Rouge, Louisiana, several nymphs were reared to maturity on the eggs of *Heliothis*, and one specimen was reared on first-instar and second-instar larvae. The eggs of *Heliothis virescens* Fabr. were present in greater numbers than those of *Heliothis obsoleta*.

No indication that the hemipterons had fed on any part of the plant was observed, either in the field or in the laboratory.

O. W. Rosewall, *Louisiana State University*, and
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Experiments with Codling Moth Bands Treated with Lead Arsenate. In experiments with newly-hatched codling moth larvae, during the year 1924–25, the fact was determined that larvae become poisoned while crawling on a surface sprayed or dusted with lead arsenate (See Hilgardia Vol. 1. 1925). The poisoning appears to be the result of the larvae swallowing particles of lead arsenate more or less accidentally. This led to the suggestion that mature larvae might be killed by treating bands with lead arsenate dust. Early in August, 1929, three different band treatments were started. The final examinations were made the first of October. Ten ounce burlap, folded to three thicknesses, was used. The results were as follows:

	Per cent of larvae dead
Untreated bands	10.6
Bands filled with lead arsenate	13.3
Bands filled with lead arsenate and underlying bark coated with lead arsenate	7.7

The poison apparently had no effect on the larvae. This fact is difficult to explain. Numerous instances were observed in which larvae were heavily coated with the poison, and in a few cases they were found literally embedded in masses of the dust, yet seemingly unaffected. The evidence suggests two possibilities. The larva swallows strictly nothing after it leaves the fruit or else it may swallow occasional particles, as does the newly-hatched larva, but the amount swallowed is insufficient to prove fatal.

RALPH H. SMITH, *University of California*

Grasshoppers vs. Salt. The following notes on food preferences of grasshoppers (Acrididae) were made some time ago while engaged in a study of their likes and dislikes with reference to their attacks on binder-twine. The species chiefly involved were *Melanoplus bivittatus* with some *M. differentialis*, and included several smaller species in less numbers. The locality was central Nebraska.

It was early learned that there was much difference in the degree of attack in various fields inhabited by essentially the same type and density of grasshopper population. During the last season in which experiments were conducted, which were carried on partly by exposing treated samples in infested fields and partly by exposing them in cages to captive insects, it was discovered that under certain circumstances even salt, which is often used in bait as an attractant, sometimes did not act as such. Treated samples, carrying salt alone, or salt plus other substances, were alike ignored and remained unattacked, even if cantaloupe juice, lemons, or "banana oil" were added. Why?

As nearly as could be judged, the reason lay in the fact that grasshoppers which had been feeding upon alfalfa or sweet clover felt no craving for salt. These leguminous plants apparently contained some principle which satisfied this craving, which remained unsatisfied in those that had fed only on the wild grasses and similar vegetation of their habitat. When the samples were presented, especially in the field, to these latter insects, they were quickly disposed of if salted, and sometimes if not. Perhaps the biological chemist can tell what substance is involved.

This brief note is published in the hope that it may perhaps explain some otherwise puzzling results obtained in experiments with grasshoppers.

Crickets, generally speaking, reacted to twines like grasshoppers in my experiments. However, crickets are apt to be most plentiful in those grain-fields where there is clover or other green lower stratum serving as a shelter, and when present are sometimes quite destructive to twine. Unlike grasshoppers, which usually devour the twine, particularly on the exterior of shooks, the crickets worked chiefly in the interior, typically making a clean cut, apparently out of sheer mischief;—as one farmer expressed it—"just to hear the bands pop!"

ALBERT P. MORSE, *Peabody Museum, Salem, Mass.*

The Lesser Corn Stalk borer (*Elasmopalpus lignosellus* Zell.) **Attacking Strawberry Plants.** A survey of the strawberry fields in the Chadbourn, North Carolina, and Plant City, Florida, districts during the fall of 1929 resulted in the finding of many plants, generally distributed over these districts, which showed evidence of some injury to the growing bud. This condition was similar to a disease known locally as "crimps," "dwarf," "French bud," or "blind plant." Closer observation, however, showed evidence, in most cases, of injury due to the feeding of the lesser corn stalk borer (*Elasmopalpus lignosellus* Zell.).

The presence of this borer in strawberry plants may have been overlooked during past years or the infestation the past season might have been the result of some unusual condition.

The method of growing strawberries in the Chadbourn district appears to be particularly favorable for the multiplication of the lesser corn stalk borer and infestation of the strawberry plants by it. The same may be true, to a limited extent, for the Plant City district. Most of the strawberry growers in the Chadbourn area grow a crop of tobacco which demands all of their attention at a time when the strawberry fields need cultivation. The result is that the strawberry fields are allowed to become overgrown with weeds and grasses until the tobacco crop is harvested. Among the weeds and grasses found in the strawberry fields are many favored host plants of the lesser corn stalk borer. When these host plants are finally cut and the strawberry fields cultivated the only available food for the larvae is the strawberry plants. In the Plant City district the general practice is to prepare the land from two to six weeks before setting to strawberries. Frequently, however, plants are set directly after the fields are prepared and thus are available for attack by any borers which might have been feeding in the recently removed weeds and grasses. Also the nursery beds, which are used as a source of plants, are sometimes allowed to grow up to weeds and thus serve as an attractive place for oviposition by the moths. The larvae then may be transferred to the fields with these plants.

It is often difficult to determine with certainty whether or not a plant is infested with the lesser corn stalk borer without pulling the plant to pieces to find the feeding galleries. The most conspicuous indication of the borer's presence is the dead and dried young leaf in the crown. This, together with the silklike tubes to which the soil particles cling, serves as the best evidence that the plant is infested.

No strawberry fields have been found in which the loss resulting from the infestation of this stalk borer was of any great economic importance. The center of the crown is often entirely killed, with the result that side shoots are produced which will probably never yield as much fruit as would have been the case with the original crown. Frequently only a portion of the crown is destroyed, in which case the remaining part of the plant appears to develop normally. One or two cases have been found where the plant was killed outright.

C. F. STAHL, *Bureau of Entomology*

Spray Coverage. Recently certain insecticide manufacturers have made claims regarding the covering qualities of their products, stating that certain brands of miscible oils were superior to lime sulfur and homemade lubricating oil emulsion.

The experiments here reported were intended to bring out, if possible, differences in coverage between certain types of oil sprays and lime sulfur. Two series of tests were conducted, including four different materials. The first series of tests were applied in the fall and the second in the spring, using the same orchard in each case.

TABLE 1. FALL APPLICATIONS,
COMMERCIAL ORCHARD, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS

Sequence	Material Used*	Dilution	Date, 1928	Upper Gun Tower		Lower Gun Ground		Total Both Guns		No. Trees	Weather
				Min.	Sec.	Min.	Sec.	Min.	Sec.		
			Dec.								
1	Commercial Oil No. 1	1–50	10	27	27	20	47	48	14	28	Quiet
2	Commercial Oil No. 2	1–15	10	24	32	19	42	44	14	29	Quiet
3	B. F. O. S.†	1.5–50	10	23	44	20	46	44	30	26	Quiet
4	Lime sulfur	1–9	10	22	42	22	45	45	27	23	Quiet
5	Lime sulfur	1–9	11	23	10	20	41	48	1	32	Quiet
6	B. F. O. S.†	1.5–50	11	20	20	21	56	42	16	25	Quiet
7	Commercial Oil No. 2	1–15	11	23	32	21	45	45	17	31	Quiet
8	Commercial Oil No. 1	1–50	11	21	44	21	50	43	34	31	Quiet, cloudy
	FRESHMAN ORCHARD, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS										
9	Commercial Oil No. 1	1–50	11	27	18	17	16	44	34	156	Quiet, cloudy
10	Commercial Oil No. 2	1–15	11	27	39	24	25	52	4	156	Quiet, cloudy
11	B. F. O. S.†	1.5–50	12	28	22	16	42	45	2	154	Quiet, cloudy
12	Lime sulfur	1–9	12	27	54	15	13	43	7	137	Moderate wind—south. Cloudy

*200 gallons of material applied in each test. A stop watch was used to record the time each application required and each gun was in operation. "Bean" outfit used at 250–300 pounds pressure.

†Boiled Fish Oil Soap Emulsion (Illinois formula).

TOTALS ON LARGE TREES

Treatment	No. Trees	Time Required	
		Minutes	Seconds
B. F. O. S.	51	86	46
Commercial Oil (No. 2)	60	89	31
Commercial Oil (No. 1)	59	91	48
Lime sulfur	55	93	28

TABLE 2. SPRING APPLICATIONS, COMMERCIAL ORCHARD, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS

Sequence	Material Used*	Dilution	Date, 1929	Upper gun Tower		Lower gun Ground		Total Both Guns		No. Trees	Weather
				Min.	Sec.	Min.	Sec.	Min.	Sec.		
			March								
1	Commercial Oil No. 1	1–50	18	25	48	21	17	47	15	28.5	Strong southwest wind.
2	Commercial Oil No. 2	1–15	18	25	0	23	13	48	13	30.5	Strong southwest wind.
3	Lime sulfur	1–9	19	26	54	21	20	48	14	23.0	Strong southwest wind.
4	B. F. O. S.†	1.5–50	19	24	42	21	20	46	2	27.0	Strong southwest wind. Shower.
5	B. F. O. S.†	1.5–50	20	27	12	23	33	50	45	27.0	Moderate southwest wind
6	Lime sulfur	1–9	20	20	30	27	54	48	24	31.0	Moderate southwest wind
7	Commercial Oil No. 2	1–15	20	24	30	25	25	49	55	24.0	Strong southwest wind.
8	Commercial Oil No. 1	1–50	20	20	51	26	37	47	29	31.0	Strong southwest wind.

*200 gallons of material applied in each test. A stop watch was used to record the time each test required and each gun was in operation. Hardie outfit used at 350 lbs. pressure.

†Boiled Fish Oil Soap Emulsion (Illinois formula).

Note: Sequence 1 and 2 applied on the same trees as in fall of 1928; all others on different trees.

TOTALS OF TIME REQUIRED FOR ABOVE TESTS

Treatment	No. Trees	Time Required	
		Minutes	Seconds
Commercial Oil No. 1	59.5	94	44
Lime sulfur	54.0	96	38
B. F. O. S	54.0	96	47
Commercial Oil No. 2	54.5	98	68

Experienced spray men made the applications but these men were instructed to spray in the usual way and had no knowledge of the tests being conducted. Two standard spray rigs of different makes were used. The results of these experiments failed to substantiate claims for the superior covering qualities of certain commercial sprays.

There seems to be a slight advantage in favor of miscible oils over lime sulfur and oil emulsion. The difference, however, is very small and it seems probable that this difference may be due to the fact that the workmen in applying the sprays can more clearly see the twigs hit with the miscible oil sprays and perhaps cease spraying slightly sooner than is the case where they were using the less visible materials. The actual time involved in making the applications does not vary greatly.

H. W. ANDERSON, W. P. FLINT, M. D. FARRAR, M. A. SMITH

A Factor Concerned in Arsenical Injury to Foliage. Special investigations of foliage injury by arsenicals were begun at the gipsy moth laboratory in 1927. Harvard University cooperated to the extent of furnishing laboratory facilities and C. R. Addinall, instructor in chemistry at that institution, was temporarily employed to assist in the studies. The following paragraphs indicate, in a brief way, the various aspects that have been given attention.

As all acids attack arsenates, one is reminded that organic acids (oxalic, citric, succinic, tartaric, tannic, etc.) and their salts are found in many plants. With this in mind the hydrogen-ion concentration of transpiration water, dew, fog, and rain water from the leaves of about 50 species of plants was investigated. A neutral to alkaline condition was indicated in the case of three species known to be very resistant to the arsenate and Bordeaux mixture, while all the other species gave an acid condition of varied pH.

Laboratory tests of the action of acidity, temperature, light, distilled water, tap water, and atmosphere on the arsenates are not sufficient, since under natural conditions the arsenates and lime on the leaf are continually moistened by transpiration, atmospheric moisture, dew, fog, and rain. Into this water is dissolved a continuous supply of well-buffered weak acid from the plant, a portion of accidental dust, and considerable carbon dioxide. Hence, the arsenates on the plant are continually put into solution by the impure water environment. An average monthly precipitation of 3.45 inches during the summer caused a relatively large volume of acidulated leaf wash to pass over a relatively small quantity of arsenate on the foliage. This precipitation was from a number of rains which occurred at intervals through a somewhat extended period of time.

To study the action of arsenates on a number of species of plants 39 plots were sprayed or dusted. Before and after various quantities of rain, determinations were made of the pH, the quantity of arsenate, the percentage of soluble arsenic, the quantity of arsenic in the tissue, the quantity of accidental dust, and the quantity of dew, per 100 square inches of leaf surface. These determinations were used in studying the effect of chemical and meteorological factors upon the degree of arsenical injury to various kinds of foliage.

The results suggested that calcium arsenate and lead arsenate were much more soluble on the acid leaf surface than in distilled water, and that calcium arsenate was, apparently, much more soluble than lead arsenate. When mixed with lead arsenate, lime apparently formed considerable calcium carbonate and calcium

arsenate (Campbell, F. L. On the role of calcium hydroxide in hydrated lime—acid lead arsenate sprays, Jour. Agr. Res., Vol. XXXII, No. 1, pp. 77–82). When heavily dosed with lime some foliage may at first give a slightly alkaline reaction with water, but the first rain of any consequence removes much of the lime, carrying with it considerable of the arsenate. The surface of the leaf then becomes acid and seemingly is able to form lead and calcium salts at the expense of the arsenate, thus setting free the arsenic acid, which would seem to be readily absorbed by the tissues, particularly in the case of young foliage which is not so thickly cutinized as mature foliage. Lime was very soluble in water on the leaf at ordinary summer rain temperature; the first 0.2 inch of rain washed off over 85 per cent of the deposit of poor grade lime and considerably less if the lime was of a high grade. It would appear, therefore, that much of the protection from arsenical injury is due to the removal of the arsenates from the foliage through the leaching effect of the lime, particularly if the latter is of a poor grade.

This brief article is not intended to be conclusive or final, for all experiments must be checked further and the chemical and physiological aspects of the problem studied in detail in relation to various meteorological conditions.

S. F. Potts, *Forest Insect Investigations, U. S. Bureau of Entomology*

INDEX IV OF AMERICAN ECONOMIC ENTOMOLOGY

The manuscript is being prepared for Index IV, which will cover the five year period from 1925 to 1929 inclusive. It is believed that it will be possible to have this publication printed and ready for distribution during the summer. The book will be about the same size as the previous index and will be of great value to all working entomologists. Further details will be sent to all members of the Association as soon as the approximate date of publication can be determined.

A. F. Burgess, *Secretary*

JOURNAL OF ECONOMIC ENTOMOLOGY

OFFICIAL ORGAN AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

APRIL, 1930

The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication at $2.50 per page for all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptable illustrations. Photo-engravings may be obtained by authors at cost.

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ANNUAL SCIENTIFIC MEETINGS: 1930–31, Cleveland; 1931–32, probably New Orleans; 1932–33, Chicago; 1933–34, undecided; 1934–35, probably Rochester.

The revoking of the Federal Asiatic Beetle quarantine recently announced is a step toward a more conservative interpretation of the quarantine act, and while it may not be satisfactory to all interested, subsequent developments may justify the belief of the Department to the effect that a continuance of this is not justified by the information at hand. It is certain that a line must be drawn somewhere. We can not afford to pay more for the protection than it is worth, all things considered. An unfortunate phase of the quarantine situation is that no one can forecast the future with certainty respecting any introduced insect. It may become more injurious as time passes and on the other hand, it may soon occupy a relatively insignificant status.

The papers presented at the annual meetings indicate the widespread and general interest in the possibilities of biological control, especially those in relation to the rearing of egg parasites. The minute *Trichogramma* has been known for years, its fluctuations in numbers have been recognized and there is a possibility that rearing and liberation of this insect may prove of material service in controlling several destructive insects. The work in several localities with *Macrocentrus* is also promising. This is a relatively unoccupied field and it is reasonable to assume that the possibilities have by no means been exhausted in the case of the few insects which have been utilized for such purposes. There is at least a fair chance that other parasites and predators, some presumably almost unknown, may be found equally amenable to artificial rearing and utilization. It is hardly to be expected that biological control with

its attractive program can replace to any great extent the artificial control measures so generally employed. It may, however, prove a valuable aid in many cases and possibly our sole dependence for certain species not easily reached by poison or contract insecticides.

Obituary

Stephen Alfred Forbes

The death of Professor S. A. Forbes on March 13th brings to a close one of the most remarkable careers known in the history of American Entomology.

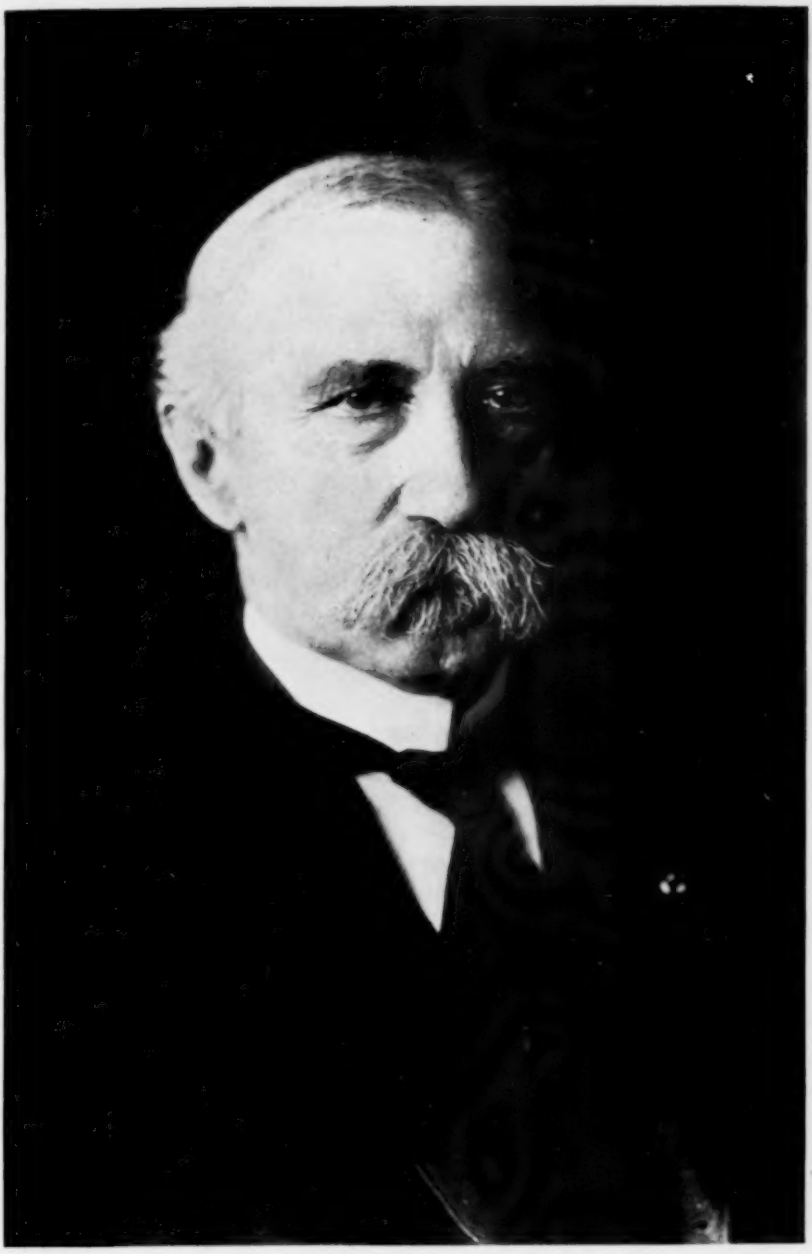
Born in 1844 (May 29), Captain in a cavalry regiment and four months a prisoner in confederate prisons during the civil war, he served his native state of Illinois during almost the entire eighty-six years of a busy life.

After student work in Beloit Academy and attendance at Rush Medical College, he began scientific work as Curator of the Illinois State Natural History Society in 1872 and taught Zoology in the State Normal University from 1875–78. He organized and was director of the State Laboratory of Natural History which was moved to Urbana when he became State Entomologist in 1882. In addition to the dual position of Director of the State Laboratory and State Entomologist, he was made Professor of Zoology and Entomology in the University in 1884, served as such until 1909 and as Head of the Department of Entomology from 1909 to 1921. He also served as Dean of the College of Science from 1888 to 1905.

He was no doubt most widely known outside his home state as Director of the State Laboratory and as State Entomologist, these offices being sufficiently distinct that outsiders not familiar with the local organization might easily have thought of two distinct individuals as in charge of these respective offices.

In Who's Who he is distinguished as "Naturalist" and he was in no sense a narrow "Entomologist" or even "Zoologist" as his biological interests covered many fields. With the reorganization of the work in 1917 he became Chief of the Natural History Survey which title he held until his death.

Among the many notable studies pursued in his laboratory, perhaps standing out most prominently are those upon the food of birds, the food of fishes, the biology of crustacea, the life history and ecology of the corn aphis and the insects injurious to the corn crop with extended attention to such pests as the corn root worm, chinch bug, Hessian fly and San Jose scale.



S. A. Forbes.

While his time was largely devoted to the organization and direction of research, his staff has included many men who sought contact with his organization as a means of perfecting their methods of work. F. M. Webster, Harrison Garman, Clarence M. Weed and Willis G. Johnson are names of a few of those who have contributed largely to entomological growth and who left his staff to assume positions of responsibility in other states.

He had the rare privilege of carrying his activities far beyond the average span of human life; of keeping in the harness until the very end of a remarkable career; of seeing the growth and maturity of many plans for scientific and educational progress and the fruition of policies of state and nation wide importance in entomological practice.

He was married December 25, 1873, to Clara Gaston Shaw, a union of marked felicity, and it is very probable that the shock of her recent death may have contributed to the illness that terminated his life.

He was a man of high ideals; a master of scientific analysis, an adept in the use of language, with a steadfast devotion to the duties of his office and recognition of obligation to the people of his state. Aside from the honors and confidence bestowed upon him by his native state, he was the recipient of many honors from societies in America and abroad.

The writer's personal acquaintance with Doctor Forbes goes back to 1883 when we met with the American Association for the Advancement of Science at Minneapolis. Our work, for many years in adjacent states, resulted in frequent correspondence and occasional conferences and his helpful suggestions and cooperation are remembered with sincere appreciation. It was Forbes who sent me a disease of cabbage worms to test at Ames. It was he who called a conference of entomologists from adjacent states to grapple with the San Jose scale problem and it was to his wider experience and mature judgment that I, with others of the younger workers in entomology, looked for leadership.

It is difficult to fully estimate today his influence on the development of entomology but he must be ranked as one of the great leaders in the growth of the science, a power not only in the state of his lifetime activity but in the nation and the world at large. In our tribute to his worth we take pride in his career and glory in the splendid achievements of a notable life.

HERBERT OSBORN

Current Notes

R. W. Brubaker, a senior student of Ohio State University, has been appointed Field Assistant in investigations of mushroom insects at Arlington, Va.

Mr. W. G. Mathers, Entomological Branch, of the Vernon B. C. laboratory, is at Syracuse University taking post graduate studies leading to the degree of master of science.

E. A. Back, Bureau of Entomology, was the guest of the National Furniture Warehousemen's Association at its convention held at the Edgewater Gulf Hotel, Biloxi, Miss., January 14 to 18.

P. N. Annand, Bureau of Entomology, formerly in charge of the sugar-beet leafhopper laboratory at Davis, Calif., has been transferred to Twin Falls, Idaho.

T. H. Jones and I. T. Guild, Bureau of Entomology, of the Gipsy-Moth laboratory, attended a meeting of the Northwestern Forest Research Council, at Springfield, Mass., on February 1.

George G. Ainslie, Bureau of Entomology of the field laboratory at West Lafayette, Ind., is spending several weeks in Washington, at the National Museum, working on the North American Crambidae.

Dr. B. B. Fulton, of the North Carolina Agricultural Experiment Station, at Raleigh, spent January 21 to 25 examining material in the collection of Orthiptera, with reference to a revision of the Orthoptera of Oregon.

F. F. Dicke, Bureau of Entomology, has accepted a transfer from the corn-borer laboratory at Monroe, Mich., to the field laboratory at Charlottesville, Va., where he will assist in investigations of the jointworm.

Prof. Herbert Osborn, research Professor of Entomology at Ohio State University was honored at the commencement of the University of Pittsburgh, February 10th, when the honorary degree of Doctor of Laws was conferred upon him by that institution.

N. F. Howard, Bureau of Entomology, attended a school for canners held on February 20 at the University of Maryland, College Park, where he took part in a discussion on the Mexican bean beetle.

Dr. R. T. Cotton, Bureau of Entomology, spent February 9 to 11 in Buffalo, N. Y., where opportunity was given him to check results of fumigations at the establishments of Larkin and Company and the Hecker H-O Cereal Company.

A. O. Larsen, Bureau of Entomology, of the bean-weevil field laboratory, Modesto, Calif., arrived in Washington on February 14, for consultation and work on manuscripts. In his absence C. K. Fisher is in charge of the laboratory.

On February 14 M. C. Lane, Bureau of Entomology, visited the Experiment Station officers of Idaho and Washington at Moscow, Idaho and Pullman, Wash., in the interest of the present season's work on wireworms in those States.

Mr. Ralph Hopping, Entomological Branch, arrived in Ottawa from Vernon, B. C. on Jan. 2, and will spend a considerable part of the winter months working with Dr. Swaine on the second half of the revision of the Lepturini.

R. Cecil, Geneva, N. Y. and J. R. Dougless, Estancia, N. M., both of the Bureau of Entomology, have been in Columbus, Ohio during the winter months to review with N. F. Howard their last season's work on the Mexican bean beetle.

W. D. Reed and Austin W. Morrill, jr., Bureau of Entomology, of the Dried Fruit Insect Laboratory, have been engaged in an investigation, in California, of such infestations of freight cars as are likely to affect shipments of dried fruits.

During the autumn, Mr. G. H. Hammond, Entomological Branch, encountered an unusually widespread outbreak of the fungus Cordyceps, in white grubs. In connection with this, a joint investigation is being carried on with Dr. J. E. Machacek, Mycologist at Macdonald College.

Miss Winifred Law, B.A., was appointed to the position of Junior Entomologist, Entomological Branch at Ottawa, dating from December 24. This position was made vacant by the promotion of Mr. Walley, sime time ago, to the position of Assistant Entomologist.

Mr. R. E. Balch, B.S.A., M.S., has been appointed to the position of Entomologist, Entomological Branch, and will take charge of forest insect investigations in the Maritime Provinces, with headquarters at Fredericton, N. B. Mr. Balch reported for duty early in February.

Mr. Paul D. Sanders, Associate Entomologist, Extension Service, University of Maryland attended the annual meeting of the New Jersey Mosquito Extermination Association held at Atlantic City, February 13, 14, and 15. Maryland is planning some extensive work on the mosquito problem in the Chesapeake Bay region.

L. W. Noble, Junior Entomologist, Bureau of Entomology, who has been a member of the force at Tallulah since his appointment in September, 1929, has been transferred to El Paso for work on the pink bollworm, and left Tallulah February 12.

H. J. Reinhard, of the Texas Agricultural Experiment Station, at College Station, has been engaged at the National Museum since January 25 on a study of the North American species belonging to the tachinid genus Winthemia. Before leaving Washington he expects to make substantial progress in a classification of these flies.

The grasshopper project has been reorganized, and Doctor J. R. Parker, formerly connected with the Department of Entomology of the Montana Agricultural College and Experiment Station at Bozeman, Mont., has been placed in charge of this work. The Laboratory at Billings, Mont., is being moved to Bozeman, where Doctor Parker will have his headquarters.

Mr. G. S. Walley, Assistant Entomologist, Entomological Branch, at Ottawa, is on three months leave of absence without pay, at the Iowa State College taking post graduate studies leading to the degree of doctor of philosophy. While there he will also make special studies of Hemiptera in connection with material from the Canadian National collection.

N. F. Howard, Bureau of Entomology, Columbus, Ohio, was in Washington February 8 to 21, to assist in miscellaneous work on manuscripts, including a revision of Farmers' Bulletin 1407, on the Mexican bean beetle, and a new manuscript on the Mexican bean beetle, prepared by L. W. Brannon and himself, to be published by the Virginia Truck Experiment Station.

The Department of Entomology, University of Maryland, has added Mr. R. E. Snodgrass of the Bureau of Entomology, Washington, D. C., to its teaching staff, part time, as Collaborating Professor of Entomology. Mr. Snodgrass is conducting a course in insect morphology, with special relation to function. This is a graduate course, offered to supplement the earlier training of the advanced students.

Cornelius B. Philip, who has recently been in Lagos, South Nigeria, working on the yellow fever investigations for the International Health Board of the Rockefeller Foundation, stopped in Washington, December 18 and 19 to compare some mosquitoes with material in the National collection. He was on his way to Montana, where he will undertake work on the Rocky Mountain spotted fever.

Mr. L. G. Gentner resigned his position as Research Assistant at Michigan Staet College, March 1, 1930, to take up similar work at Talent, Oregon. Mr. Gentner will be following the same type of work that he carried on in Michigan. Mr. Franklin Sherman III, of Cornell University has been appointed to take the place vacated by Mr. Gentner.

W. D. Reed, Bureau of Entomology, of the field laboratory at Fresno, Calif., went to Indio, Imperial Valley, on February 5 to advise and make fumigation tests for the Deglet Noor Date Growers Association. The delivery of dates begins about September 5 and lasts until about January 1. All dates are fumigated on receipt at the packing house, and most of them are again fumigated just before shipment.

The officers of the Chatham Ontatio Laboratory, Entomological Branch, are studying the winter mortality of the European corn borer, in standing stalks and below ground, both in the field and in the laboratory, and are making determinations of lethal temperatures for the larvae under various conditions, as part of the study of climatic limitations on the corn borer's distribution in Canada.

George B. Wagner, Bureau of Entomology, in charge of investigations of flour-mill insects, attended the Kansas Wheat Belt Conference held at Wareham Hotel, Manhattan, Kans., on November 9. It was there planned that Mr. Wagner should assist George Montgomery, of the Extension staff of the Kansas State Agricultural College, in the conducting of a number of grain-grading schools to be held in Kansas in April.

R. E. Campbell, Bureau of Entomology, Alhambra, Calif., has been granted a furlough to undertake special studies at the University of Minnesota, St. Paul, beginning in January, 1930. He visited Washington, D. C., on December 17, for conference in regard to the pepper weevil and wireworms in California. En route to St. Paul, Minn., from Washington, he stopped over at Columbus, Ohio, and attended the entomological meetings at Des Moines, Iowa.

On February 21 the field laboratory at Biloxi, Miss., was visited by five officials of the State Plant Board of Mississippi, these being Dr. L. E. Miles, Pathologist, J. M. Langston, Entomologist, and three Inspectors, R. P. Colmer, H. Gladney, and Henry Deitrich, located respectively at Moss Point, Ocean Springs, and Lucedale. On February 25 the same field laboratory had as a visitor C. E. Smith, in charge of the field laboratory at Baton Rouge, La.

Mr. Paul D. Sanders, Associate Entomologist, Extension Service, University of Maryland, has returned to the campus after five months leave. Mr. Sanders has completed his residence for the Doctor's degree, at Harvard University. Six weeks

of his leave were spent at the Harvard University. Six weeks of his leave were spent at the Harvard Tropical Research Station, at Soledad, Cuba. His collection of tropical insects, largely from Cienfuegos and surrounding Cuban territory have been presented to the University of Maryland, and will be incorporated in the collection at an early date.

In response to a request from the citrus growers of northern California, E. A. McGregor, Bureau of Entomology, of the field laboratory at Lindsay, Calif., went to Oroville, where on January 16, he addressed the growers on the subject of control of the citrus thrips. This address was a part of the Citrus School program of that date. Particular stress was placed by Mr. McGregor on the part that dusting with finely ground sulphur is playing in the control of this insect in central California.

Mr. E. Graywood Smyth, formerly of the Bureau of Entomology, and for several years entomologist of the Insular Agricultural Experiment Station in Porto Rico, has accepted a contract position as entomologist for W. R. Grace and Company on their sugar estates in Peru. Until recently he has been employed as entomologist for John Powell and Company, Pyrethrum Specialists, in New York City. His permanent address will be Hacienda Cartavio, Salaverry, Peru, and he will devote himself largely to the control of the sugar cane moth stalk borer, *Diatraea saccharalis*.

Perez Simmons, Bureau of Entomology, in charge of the field laboratory at Fresno, Calif., for the study of dried-fruit insects, writes that the periodical exchange which he started last year has been reogranized for 1930. This year 16 laboratories of the Bureau on the Pacific Coast are cooperating. "There are 446 numbers, of 35 periodicals, in the exchange. Assuming that but one man at each station to which a periodical is sent, reads it, the exchange will be equivalent to 1,047 individual loans of periodicals."

The ninth annual conference of the North Central States Entomologists was held at Purdue University, Lafayette, Indiana, March 5 and 6. Eighty persons (not including students and members of other departments) from 15 states and from Canada registered. Informal discussions of the important insect problems of the north-central states occupied the greater part of the two days. The annual dinner was held the night of March 5, Dr. Edward C. Elliott, President of Purdue University, acting as toastmaster. J. J. Davis acted as chairman of the Conference. The next meeting (March, 1931) will be held at Urbana, Illinois.

On February 27 William Middleton, Forest Insect Investigations, and Dr. Floyd F. Smith, of the Division of Cereal and Forage Insects, both of the Bureau of Entomology, visited Leesburg, Va., to demonstrate the fumigation control of the boxwood leaf miner, with which they have been experimenting for several years. The demonstration was conducted at the request of Mr. Lintner, County Agent of Loudoun County, who has succeeded in arousing in that county a great deal of interest in boxwood and in the control of the leaf miner.

D. E. Fink, Bureau of Entomology, in charge of the field laboratory at Philadelphia, Pa., advises that Dr. Jaymie R. Peirera, Professor of Pharmacology of Sao Paulo Medical School, Sao Paulo, Brazil, visited his laboratory on January 13, to obtain first-hand knowledge of the "Electro-Gutzeit Apparatus" perfected at this laboratory. This apparatus has been the subject of inquiry from State experiment stations, entomologists, chemical companies, and the Research Institute, Mel-

bourne, Australia. Word has been received that Dr. N. F. True, chief chemist for Mead, Johnson and Co., Evansville, Ind., has had a similar apparatus constructed for work in infant diet.

A large shipment of cocoons of the oriental hag moth, *Cnidocampa flavescens* Walk., reached the Gipsy-Moth Laboratory on February 13. The shipment consisted of approximately 779,000 cocoons collected in Fuji and Mikawa, Japan, under the direction of T. R. Gardner, of the Bureau's Japanese and Asiatic Beetle Investigations. Over 600 Japanese school children participated in the collecting, and Mr. Gardner writes that examination of sample lots of cocoons showed that nearly 50 per cent contained larvae of the tachinid parasite, *Chaetexorista iavana* B & B. It is hoped that the liberation of admits of this parasite made last year in infestations of *Cnidocampa flavescens* in the vicinity of Boston, together with those which it should be possible to make this year, will result in its establishment.

The annual conference of Federal and State administrative officials, scientists, and others, on the research program for the control of the European corn borer was held at the Department of Agriculture in Washington, D. C., February 11. The complete research program for the year, and reports of several committees on important phases of the work, were presented and considered. The purpose of this meeting, as heretofore, was to provide for a complete coordination of the various projects, both Federal and State, for research on the corn borer, to arrange for desirable replication of experiments and to prevent unnecessary duplication of experimental work. It was further intended to have this direct contact with the program for research on the corn borer afford an opportunity for administrative review and constructive criticism, to the end that the program should each year be in every respect as complete and satisfactory as possible.

On February 21 R. A. St. George, Bureau of Entomology, received a report from S. R. Broadbent, Supervisor of the Unaka National Forest, with headquarters at Bristol, Tenn., that an outbreak of the southern pine beetle has been located along Scioto Creek. The attack of the beetle was made last fall, and the overwintering brood was recently discovered. This information is of particular interest, since similar attacks in the French Broad Division of the Pisgah National Forest and adjoining tracts also occurred last fall, and have now resulted in heavy broods of this beetle. The trees in both forests along the boundary between western North Carolina and eastern Tennessee were probably attacked at about the same time. The low temperatures of November 29 and 30, 1929, were effective in killing the brood that remained between the bark and the wood, but the more developed brood that had penetrated the outer bark escaped being affected. Unless zero temperatures are experienced in March, or excessive rainfall occurs this spring, there is apt to be a rather heavy emergence of the beetles early in the summer.

Conferences were held in Washington, D. C., February 10, 1930, in Room 411, Bieber Building, on the Codling Moth and Peach Moth. The following were present: E. N. Cory, H. S. McConnell, G. S. Langford, P. D. Sanders, W. T. Henerey and P. K. Harrison, Univ. Md.; W. S. Hough, Va. Agr. Exp. Sta.; Geo. A. Dean, Kan. Agr. Coll.; C. H. Alden, Ga. State Bd. Ent.; J. S. Houser, R. B. Neiswander and L. L. Huber, Ohio Agr. Exp. Sta., T. J. Headlee and B. F. Driggers, N. J. Agr. Exp. Sta.; T. L. Guyton and J. R. Stear, Pa. Bureau Plant Ind.; H. N. Worthley, S. W. Frost and H. E. Hodgkiss, Pa. State Coll.; L. A. Stearns, Del. Agr. Exp. Sta.; Philip Garman, Conn. Agr. Exp. Sta.; J. J. Davis, Purdue Univ.; R. H. Pettit, Mich.

Agr. Coll.; D. M. Daniel, N. Y. Agr. Exp. Sta.; L. M. Peairs, W. Va. Agr. Exp. Sta.; C. O. Eddy, S. C. Agr. Exp. Sta.; W. A. Ross, Ont. Agr. Coll.; R. B. Arnold, Tobacco By-Products & Chem. Corp.; C. G. Woodbury, Natl. Canners' Association; A. L. Quaintance (Chairman), L. C. McAlister, Jr., Loren B. Smith, B. A. Porter, Luther Brown, E. H. Siegler, J. W. Lipp, F. H. Lathrop, Wm. P. Yetter, Jr., H. W. Allen, E. J. Newcomer, G. A. Runner, J. L. King, F. L. Campbell, and F. M. Wadley, U. S. Bur. Ent.; M. B. Waite, J. R. Magness and H. C. Diehl, U. S. Bur. Plant Ind., and R. C. Roark and C. M. Smith, U. S. Bur. Chem. & Soils. Minutes of the conferences will be issued in mimeographed form and sent to those in attendance. Upon request the minutes will also be sent to others interested as long as the supply lasts.

Horticultural Inspection Notes

Mr. George M. Jones was transferred from Laredo, Texas, to assume charge of the work at the Port of Zapata, Texas, on March 4, 1930.

That part of Baldwin county, Alabama, formerly restricted under the State sweet potato weevil quarantine, was released on January 14, 1930, from such restriction.

Mr. C. W. Shockley was transferred from the Pink Bollworm project to the Mexican Border service on March 10, 1930. .Mr. Shockley has been assigned to the Port of Brownsville, Texas.

The Memphis, Tenn., transit inspection station, for the purpose of aiding in the enforcement of the phony peach disease quarantine, was discontinued for the season on February 20.

Mr. R. B. Haller who has been stationed at Del Rio, Texas, for several years was put in charge of the Plant Quarantine and Control Administration's activities at the port of entry at Roma, Texas, on February 1, 1930.

Mr. R. N. Dopson, assisting in the enforcement of the phony peach disease quarantine and in transit inspection work at Birmingham, Ala., was transferred to Chicago on March 3 and was succeeded at Birmingham by C. E. Martin.

A quarantine against the transportation into California of hop sets, hop roots, and hop cuttings from all States except Oregon, has been issued by the Director of Agriculture of California, effective January 31, 1930.

On March 3, the Pennsylvania Railroad was fined $1400 for violations of quarantines on account of the Japanese beetle, Asiatic beetle and Asiatic Garden beetle, involving the transportation of seven carloads of soil from New Jersey to Michigan.

Mr. G. W. R. Davidson, in field charge of the enforcement of the Federal phony peach disease quarantine, made a study during March of the desirability of undertaking transit inspection at Texarkana and New Orleans in connection with the administration of this quarantine.

Mr. R. H. Bell, Director of the Bureau of Plant Industry of the Pennsylvania Department of Agriculture was incapacitated for several weeks during January and February and unable to be at his office. Mr. T. L. Guyton was made Acting Director for the period of Mr. Bell's absence.

Mr. Claud H. Wallis, Mr. C. F. Haller and Mr. Keim E. Miller were appointed Junior Plant Quarantine Inspectors and assigned in February, 1930, for duty at the Port of Nogales, Arizona, the Port of El Paso, Texas and the Port of Roma, Texas, respectively.

A sub-committee of the Appropriations Committee of the House of Representatives spent about two weeks in Florida late in February and early in March conducting a hearing on the Department of Agriculture estimates for the continuation of the Mediterranean fruit fly eradication and quarantine work.

On February 8, 1930, the Plant Quarantine and Control Administration issued "Supplement No. 2 to Instructions on the Disinfection of Nursery Products for the Japanese and Asiatic Beetles." This supplement changed the specifications for the disinfection of soil about the roots of plants with carbon disulfide emulsion.

Mr. J. S. Wieman has been appointed nursery inspector at large by the Oregon State Board of Horticulture. This is a new position for which an appropriation was made at the last session of the legislature. Mr. Wieman's duties will include nursery inspection and the assistance of nurserymen in the control of plant diseases and insect pests.

The California Department of Agriculture revised the State Oriental fruit moth quarantine, effective January 31, 1930, to add the States of Rhode Island, Massachusetts, and Michigan to the list of those from which the fruits, trees, and parts thereof, of apple, peach, cherry, etc., and the used containers of such fruits, are not admissible into California.

The Oregon Alfalfa Weevil quarantine has been amended to allow the shipment of alfalfa meal from weevil-infested States throughout the year provided the meal is ground in mills built on plans approved by the Bureau of Entomology alfalfa weevil specialists at Salt Lake City.

Mr. Charles A. Cole, Secretary of the Oregon State Board of Horticulture, reports that a quarantine order against the bringing in of hop roots from all States except California has been issued by the State of Oregon. The quarantine was adopted for the purpose of preventing the introduction of the Hop Downy Mildew which is now present in Colorado and has been reported in the past in various parts of the United States.

Dr. Walter A. McCubbin, Plant Pathologist of the State Department of Agriculture at Pennsylvania, was appointed on February 1 to take charge of the certification of Florida products for intrastate and interstate movement under the Federal and State quarantines on account of the Mediterranean fruit fly. This position involves supervision of the work at packing houses, storages, canneries, and all other details connected with the issuance of permits in Florida under the fruit fly quarantine.

The pink bollworm infestation in the Salt River Valley of Arizona, which was discovered October 4, 1929, appears to be confined to that portion of the Valley east of Tempe. A noncotton zone has been established by the State covering a total of 144,400 acres. Within this area 35,000 acres were planted to cotton in 1929. The noncotton zone is surrounded by a protective or buffer zone which extends three miles beyond the noncotton zone. Congress has passed an appropriation of $587,500 for the cleanup of the cotton fields throughout the noncotton zone and in some parts

of the buffer area. Provision is also being made for compensation to the farmers in the noncotton zone area.

As a result of the discontinuance by the U. S. Department of Agriculture of the Mediterranean fruit fly field inspection work in Florida, Dr. Wilmon Newell, who has been the Federal administrative agent in carrying on this work, has resigned his Federal position and the Government regulatory work in connection with fruit fly activities in Florida has been placed under the direction of Dr. W. C. O'Kane, chairman of the Federal Fruit Fly Board, it was announced to-day by Lee Strong, Chief of the Plant Quarantine and Control Administration. The department continues cooperation with the Florida State Plant Board, of which organization Doctor Newell is the executive officer. Doctor O'Kane has been chairman of the Federal Fruit Fly Board since its creation by Secretary Hyde on January 9.

Early in February the Plant Quarantine and Control Administration made arrangements for the certification of the reshipment of Florida sterilized host fruits and host vegetables from Washington, Baltimore, and Pittsburgh to points in Virginia, West Virginia, and Ohio. Such certification at Washington was placed under the direction of the Administration Inspection House; that at Baltimore is being handled by J. W. Kelley, formerly of the Japanese Beetle inspection service; while work at Pittsburgh is under the direction of Clyde B. Beamer. Four crews of two men each were assigned to road station work at the southern and western boundaries of Maryland and Pennsylvania to enforce the requirements.

The Southern Plant Board met at Jackson, Mississippi on February 5 and 6, 1930, in connection with the Annual Session of the Southern Agricultural Workers. The following States were represented: Texas, Oklahoma, Louisiana, Mississippi, Alabama, Georgia, South Carolina, North Carolina, and Tennessee. Mr. E. R. Sasscer and Mr. R. E. McDonald of the Plant Quarantine and Control Administration were also present. The subjects discussed included foreign plant quarantines, the unification and coordination of nursery inspection in the south, Mediterranean fruit fly, pink bollworm, and phony peach disease. The following are the officers for the ensuing year: B. P. Livingston, President; Paul Millar, Vice-President; M. S. Yeomans, Secretary-Treasurer; R. W. Harned, and R. W. Leiby, representatives on the National Plant Board. The next meeting is to be held at Atlanta early in February, 1931.

The Federal quarantine on account of the Japanese beetle was revised, effective March 1, to extend the regulated area to include one county in Massachusetts, as well as certain new territory in Connecticut, New York, Pennsylvania, Maryland, Delaware, and Virginia. Under this revision the regulated area is divided into generally and lightly infested areas. Restrictions on the movement of farm products apply to such movement from the generally infested areas but do not affect the movement of these articles from the lightly infested area. The shipment of other restricted articles both from the generally infested to the lightly infested area and from either to points entirely outside the regulated areas, is restricted under this modification. A further change of interest to shippers increases the classes of bulbs exempt from Japanese beetle certification.

The Federal quarantine on account of the Asiatic Beetle and the Asiatic Garden beetle was revoked by the Secretary of Agriculture, effective March 1, 1930. The area affected consisted of the District of Columbia, the State of New Jersey, anp

portions of Connecticut, New York, Pennsylvania, and Virginia. In announcing the revocation of the quarantine, the Secretary stated that "the Department of Agriculture has reached the conclusion that a continuation of Federal restrictions on the interstate movement of nursery products and soil, to prevent the spread of these insects, is not justified by the information at hand. In placing the quarantine a year ago, the Department felt that dissemination should be prevented until the significance of these species could be weighed more carefully and further observations made. The past year's work has indicated that their potential danger to the United States does not justify the expenses of quarantine administration and the losses resulting from the imposition of restrictions. In revoking this quarantine, the Department of Agriculture is following the precedents of past years in removing plant quarantine restrictions whenever it becomes apparent that they are no longer justified by the available facts."

Recent orders issued by the Plant Quarantine and Control Administration with respect to the transportation of Florida host fruits and vegetables include the following: PQCA-261, "Diversion Restrictions on Florida Host Fruits and Vegetables Modified"; PQCA-262, "Period of Movement of Host Fruits and Vegetables from Florida to Southern and Western States Extended to February 28, 1930"; PQCA-263, "Modification of the Restrictions on the Movement of Florida Host Fruits and Vegetables from the District of Columbia and the States of Maryland and Pennsylvania to Nearby Points in Virginia, West Virginia and Ohio"; PQCA-264, "Extension of Production and Harvesting Period of Florida Cantaloupes to June 15, 1930"; PQCA-266, "Waterproof Fabric Mesh Bags Authorized as Containers for Florida Host Fruits and Vegetables"; PQCA-267, "Production of Cotton in and Intrastate Movement from Eradication Areas in Florida"; PQCA-268, "Release of West Florida from Mediterranean Fruit Fly Quarantine Restrictions"; PQCA-269, "Extension of Production and Harvesting Period of Florida Citrus and Other Host Fruits to April 15, 1930"; PQCA-270, "Florida Host Vegetables Produced Outside Eradication Area Authorized to be Shipped by Express in Less Than Car Lots"; and PQCA-271, "Additional Method of Sterilizing Florida Citrus Fruits by Refrigeration, Authorized."

The sixth annual meeting of the Central Plant Board was held at Lafayette, Indiana, on March 6, 1930. Nine States: Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Ohio, and Wisconsin were represented. On account of the apparent wide distribution of Rose yellows, a resolution was passed asking the Federal Department of Agriculture to make an investigation to determine its distribution, and to determine the sources from which healthy American grown stock can be procured, and requesting the Plant Quarantine and Control Administration not to prohibit the importation of foreign grown rose stock until such investigation has been completed and sources from which an adequate supply of rose stock free from yellows can be procured. The members of the Board are unanimous in the belief that the Mediterranean fruit fly will never become a serious pest in any of the north central States and that it probably will not be able to maintain itself very far north of the Gulf Coast. The Secretary was asked to renew the request of a year ago that Plant Quarantine No. 38 be amended so as to prohibit the interstate movement of the Mahonias, except *Mahonia repens*, between the thirteen States which are engaged in the eradication of the common barberry because the Mahonias are not being eradicated in some of the States. The next place of meeting is Urbana,

Illinois. The officers for the next year are: E. L. Chambers, President; P. A. Glenn, Secretary and Treasurer; Geo. A. Dean and A. G. Ruggles, members of the National Plant Board.

The National Plant Board held its annual meeting at Orlando, Florida on January 11 to 15, 1930. The full membership was present as follows: W. C. O'Kane, Durham, N. H. (Chairman); G. A. Dean, Manhattan, Kansas (Vice-chairman); W. A. McCubbin, Harrisburg, Pa. (Secretary); Oscar Bartlett, Phoenix, Arizona; R. W. Harned, A. & M. College, Mississippi; W. C. Jacobsen, Sacramento, California; R. W. Leiby, Raleigh, N. C., and A. G. Ruggles, St. Paul, Minnesota. The Board spent a part of its sessions investigating the Mediterranean fruit fly problem and concluded that "this pest shows potentialities for damage so great that it should be suppressed at almost any cost"; * * * "That this program undertaken by the PQCA and the Florida State Plant Board not only effectively safeguards the rest of the country from this pest but gives an assuring prospect of its ultimate eradication * * * [and that] the National Plant Board earnestly urges the PQCA and the Florida Plant Board to continue their eradication efforts on both an extensive and intensive scale until the final suppression of this pest is absolutely assured." Final agreement among the various States on certain principles relating to nursery inspection methods was announced, and seven such principles were recommended for adoption by all States. Other subjects discussed were larch canker, the Salt River Valley outbreak of the pink bollworm, the importation of foreign fruits through northern ports and their possible reshipment south; the danger of airplanes being responsible for pest introduction; terminal inspection of parcel post; the increasing spread of the Argentine ant, and the fumigation of nursery stock. It was further announced that for several years the Board has had under preparation a statement embodying the "Principles of Quarantine," and that this statement has now been submitted to the Regional Boards for consideration.

Apicultural Notes

Mr. Charles A. Reese, State Bee Inspector, Columbus, Ohio, attended the American Honey Producers' League, February 4, 5, and 6, which was held at Milwaukee, Wisconsin.

J. E. Eckert, Bureau of Entomology, of the Intermountain Bee Culture Field Laboratory, Laramie, Wyo., attended the meeting of the Wyoming Beekeepers' Association at Thermopolis, Wyo., on December 12 to 14, and addressed the meeting on "The flight range of the honeybee."

C. E. Burnside and W. J. Nolan, Bureau of Entomology, attended the annual meeting of the Maryland State Beekeepers' Association, in Baltimore, on January 8th. Doctor Burnside spoke on "The present status of American foulbrood control," and Mr. Nolan gave a talk on "Races of honeybees."

Dr. A. P. Sturtevant, Bureau of Entomology, in charge of the Intermountain Bee Culture Field Laboratory, Laramie, Wyo., attended the meeting of the Idaho State Beekeepers' Association, and the conference of apiary inspectors, at Buhl, Idaho, December 16 and 18. Doctor Sturtevant spoke on "The various problems associated with apiary inspection."

The Ohio Beekeepers' Association at their convention held at the Ohio State University, February 6, 7, and 8 went on record as opposing the Corn Sugar bills, Senate Bill (S-685) and House Bill (H.R. 2154). This bill if passed would leaglize corn sugar being mixed with any other sweet without the declaration of such on the label.

W. J. Nolan, Bureau of Entomology, attended the annual meeting of the New Jersey State Beekeepers' Association, at Trenton, on January 16 and 17, and spoke on "The United States honey grades," and "The work of the Bee Culture Laboratory." On January 21 and 22 he attended the annual meeting of the Pennsylvania State Beekeepers' Association, at Harrisburg, where he gave a talk on "Characteristics of the various races of honeybees," and also acted as judge of the apiary products at the Farm Show.

Dr. Warren Whitcomb, jr., Bureau of Entomology, of the Southern States Bee Culture Field Laboratory, Baton Rouge, La., attended the meeting of the Alabama State Beekeepers' Association at Montgomery, Ala., on November 7 and 8. After the meeting Doctor Whitcomb, accompanied by L. T. Floyd, Provincial Apiarist of Manitoba, and H. C. Short, President of the Alabama State Beekeepers' Association, visited a large number of the queen breeders and package-bee producers in the heart of the package-bee industry in Alabama.

Jas. I. Hambleton, after attending the meetings of the American Association for the Advancement of Science at Des Moines, Iowa, visited the Intermountain Bee Culture Field Laboratory, at Laramie, Wyo., he then went to the beekeeping centers of the Pacific Coast States. He returned by way of Baton Rouge, La., where he visited the Southern States Bee Culture Field Laboratory, and attended the meetings of the American Honey Producers' League in Milwaukee, Wis., on February 3 to 6. Mr. Hambleton then attended the meeting of the Ohio State Beekeepers' Association at Columbus, Ohio.

W. J. Nolan, Bureau of Entomology, attended the Extension School of the Department of Horticulture of West Virginia University, at Inwood, W. Va., on February 10, and gave a talk on "The use of bees in orchards for pollinating purposes." It is noticeable that fruit growers are giving more attention to the artificial control of pollination in orchards by the use of honeybees than they have given in the past. At the present time many of the producers of package bees are making arrangements to furnish exclusively package bees for purposes of pollination.

The Ohio Beekeepers' Association held their Winter Meeting, February 6, 7, and 8 in conjunction with Farmers' Week at the Ohio State University. The officers elected for the coming year were: E. E. Agler, Columbus, President; Alan Eby, West Elkton, Ohio, Vice-President; W. E. Dunham, Columbus, Secretary and Treasurer. Speakers outside the state included Dr. James I. Hambleton, Director of the Bee Culture Laboratory, Washington, D. C.; Dr. E. F. Phillips, Professor of Apiculture, Cornell University; Mr. Frank C. Pellett, Associate Editor of American Bee Journal, Hamilton, Ill., Dr. H. E. Barnard, President of the American Honey Institute, Indianapolis, Indiana; Morley Pettit, Georgetown, Ontario and Frank Todd, in charge of Apiary Inspection in California.

On a recent trip to the Pacific Coast Jas. I. Hambleton, Bureau of Entomology, stopped at the Oregon Agricultural College, at Corvallis, and at several branches of the University of California, as well as at a number of high schools and junior colleges, all of which are vitally interested in the future of beekeeping research, and have offered the Department of Agriculture excellent facilities and accommodations for carrying on research at their respective institutions. The exact location for a research laboratory on the Pacific Coast has not been selected. Cooperation on the part of beekeepers is also assured, and a number of the county associations as well as individual beekeepers have offered the use of their apiaries and other facilities for investigational work.

At the annual convention of the American Honey Producers' League, held in Milwaukee, Wis., February 4 to 6, a resolution was adopted asking the Department of Agriculture to appoint extension specialists in apiculture. The Association of Apiary Inspectors of America, which held its annual meeting at the same time, adopted a resolution requesting that reports on the occurrence and distribution of American foulbrood, and the progress made in its eradication, be included in the Insect Pest Survey. As soon as the machinery is perfected for reporting the findings on American foulbrood to the Insect Pest Survey the information should be very helpful in giving a clear-cut picture of the situation as to bee diseases in the United States, and enable the industry to see what progress is being made.

W. J. Nolan, Bureau of Entomology, has just attended the Southern States Beekeepers' Conference held at Baton Rouge, La., February 26 to 28, and reports a splendid meeting, with representatives present from 17 states. Mr. Nolan spoke on "Federal work of aid to the beekeeper." Dr. Warren Whitcomb, Jr., and Dr. E. Oeretel, of the Southern States Bee Culture field laboratory, also addressed the meeting, their respective topics being "Standardization of shipping cages for package bees," and "The number of egg tubules in the queenbee." Dr. E. F. Phillips, George S. Demuth, and Kenneth Hawkins, all formerly connected with the Bee Culture Laboratory, were present and appeared on the program. Dr. H. E. Barnard, President of the American Honey Institute, gave a talk on the nutrition of children, with special reference to honey. The next meeting of the Southern States Beekeepers' Conference will be held at Montgomery, Ala.

Notes on Medical Entomology

W. G. Bruce, Bureau of Entomology, went from Dallas, Tex., to Sanford, Fla., in the first week of January, where he has undertaken a survey of conditions relating to the cattle grub.

From January 20 to January 26 H. S. Peters, Bureau of Entomology, was engaged upon an investigation of the cattle grub at Burkes Garden, Va., with particular reference to control by local residents. The work was done in cooperation with L. I. Case, Extension Animal Husbandman, V.P.I.

F. C. Bishopp early in January went to the region of Sheboygan Falls, Wis., where he conferred with county agents and addressed meetings of farmers in regard to control of the cattle grub. He also conferred with the county agent, and with farmers at Gold Hill, Iowa, concerning a local program for the eradication of horse bots.

D. G. Hall, Bureau of Entomology, engaged in investigations of the eye gnat, writes that a careful study of the literature indicates that the generic name Hippelates has been incorrectly used. "The change is noted by Bezzi, 1928, Diptera of the Fiji Islands, British Museum Natural History, p. 148. Bezzi states "Doctor Kertesz (Ann. Mus. Nat. Hung. XII, p. 674, 1914) from an examination of the genotype, in the British Museum, states that Cadrema Walker, 1860, must be substituted for Hippelates, Loew, 1863."

F. C. Bishopp, Bureau of Entomology, left Washington February 3, to attend the meeting of the Southern Agricultural Workers, at Jackson, Miss., February 5–7. After this meeting he visited the field laboratory at Tallulah and New Orleans, La., and Sanford and Orlando, Fla., and conferred at Baton Rouge with members of the Division of Animal Industry of the Louisiana State Experiment Station.